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(54) 【発明の名称】 ガスタービン用動翼及びその製造法とそれを用いたガスタービン

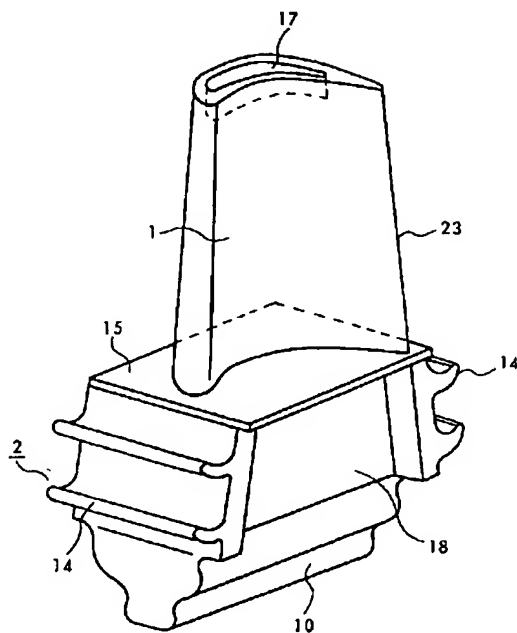
(57) 【要約】

【目的】 クリープ強度に優れた且つ粒界割れのないガスタービン用動翼及びその製造法とそれを用いたガスタービン及び複合発電プラントシステムを提供する。

【構成】 粒界強化元素を低減させたNi基超合金を用い、翼部を単結晶、残りを柱状晶としたガスタービン動翼とそれを用いたガスタービン。

【効果】 ガスタービンの熱効率を35%以上及び蒸気タービンとの複合発電熱効率を45%以上に向上できる。

図 1



【特許請求の範囲】

【請求項1】翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有するガスタービン用動翼において、前記翼部と前記プラットフォーム及び前記シャンク部内の1部とが単結晶であり、該単結晶からなる部分を除いた部分が一方凝固した柱状晶である一体の铸件からなることを特徴とするガスタービン用動翼。

【請求項2】翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有するガスタービン用動翼において、前記翼部と前記プラットフォーム及び前記シャンク部の1部とが単結晶であり、前記単結晶からなる部分以外の全部が一方凝固した柱状晶である一体の铸件からなることを特徴とするガスタービン用動翼。

【請求項3】請求項1又は2において、前記ダブティル部から翼部先端にかけて内部に一体に連なる冷媒通路が設けられているガスタービン用動翼。

【請求項4】翼部と、該翼部に連なる付根部とを有し、一体の铸件からなるガスタービン用動翼において、前記翼部と前記プラットフォーム及び前記シャンク部の1部とが単結晶であり、前記単結晶からなる部分以外が一方凝固した柱状晶であり、前記翼部先端から前記付根部に向って凝固していることを特徴とするガスタービン用動翼。

【請求項5】翼部と、該翼部に連なる付根部とを有し、一体の铸件からなるガスタービン用動翼において、前記翼部と付根部との結晶方位の差が2～8度であることを特徴とするガスタービン用動翼。

【請求項6】翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有するガスタービン用動翼において、該動翼は一体の铸件からなり、各部の結晶方位の差が2～8度であることを特徴とするガスタービン用動翼。

【請求項7】請求項1～6のいずれかにおいて、前記铸件は重量で、C0～0.20%、Cr2～16%、Al4～7%、W2～15%、Ti0.5～5%、Nb0～3%、Mo0～6%、Ta0～12%、Co0～10.5%、Hf0～2%、Re0～4%、B0～0.035%、Zr0～0.035%、及び残部が58%以上のNiからなるガスタービン用動翼。

【請求項8】重量で、C0～0.20%、Cr2～16%、Al4～7%、W2～15%、Ti0.5～5%、Nb0～3%、Mo0～6%、Ta0～12%、Co0

～10.5%、Hf0～2%、Re0～4%、B0～0.035%、Zr0～0.035%、及び残部が58%以上のNiからなり、前記C量とB及びZr量的一方又は両方がA(C0.20%、B+Zr0%)、B(C0.05%、B+Zr0%)、C(C0%、B+Zr0.01%)、D(C0%、B+Zr0.035%)及びE(C0.1%、B+Zr0.025%)の範囲内にあり、結晶方位の差が2～6度であることを特徴とするガスタービン用動翼。

10 【請求項9】翼部が単結晶及びダブティルが柱状晶を有し、重量で、C0.03～0.1%、Cr5.5～9.0%、Co8.5～10.5%、W8～11%、Re1.0～3.5%、Mo0.3～1.0%、Ta3～4%、Al5～6%、Ti0.5～1.5%、Hf0.5～1.0%、B及びZrの1種又は両者が0.005～0.025%、及び残部がNiと不可避不純物であり、結晶方位の差が単結晶部分で8度以下及び柱状晶部分で15度以下であることを特徴とするガスタービン用動翼。

【請求項10】翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有するガスタービン用動翼において、前記翼部が単結晶であり、前記ダブティルが一方凝固した柱状晶からなる一体の铸件であり、前記ダブティル部から翼部先端にかけて内部に一体に連なる冷媒通路が設けられ、前記铸件は重量で、C0～0.20%、Cr2～16%、Al4～7%、W2～15%、Ti0.5～5%、Nb0～3%、Mo0～6%、Ta0～12%、Co0～10.5%、Hf0～2%、Re0～4%、B0～0.035%、Zr0～0.035%、及び残部が58%以上のNiからなり、前記C量とB及びZr量的一方又は両方がA(C0.20%、B+Zr0%)、B(C0.05%、B+Zr0%)、C(C0%、B+Zr0.01%)、D(C0%、B+Zr0.035%)及びE(C0.1%、B+Zr0.025%)の範囲内にあり、 γ 相マトリックス内に γ' 相が析出した組織を有し、前記 γ 相の結晶方位の差が2～6度であることを特徴とするガスタービン用動翼。

40 【請求項11】コンプレッサによって圧縮された燃料ガスを静翼を通してディスクに植設された動翼に衝突させて該動翼を回転させるガスタービンにおいて、前記動翼は3段以上有し、該動翼の初段が翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンクと、該シャンクの両側に設けられた突起からなるフィンと、前記シャンクに連なるダブティルとを有し、前記翼部が単結晶であり、前記ダブティルが一方凝固した柱状晶からなる一体の铸件からなることを特徴とするガスタービン。

50 【請求項12】コンプレッサによって圧縮された燃焼ガ

スを静翼を通してディスクに植設された動翼に衝突させて該動翼を回転させるガスタービンにおいて、前記燃焼ガス温度が1,500℃以上であり、前記動翼を3段以上有し、該動翼の初段入口での前記燃焼ガス温度が1,300℃以上であり、前記動翼の初段は全長が200mm以上で、その翼部が単結晶であり、前記付根部が一方方向凝固した柱状晶である一体の鋳物からなり、発電容量が5万KW以上であることを特徴とするガスタービン。

【請求項13】コンプレッサによって圧縮された燃焼ガスを静翼を通してディスクに植設された動翼に衝突させて該動翼を回転させるガスタービンにおいて、前記燃焼ガス温度が1,500℃以上であり、前記動翼を3段以上有し、該動翼の初段入口での前記燃焼ガス温度が1,300℃以上であり、前記動翼の初段は全長が200mm以上で、

前記動翼の初段は翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有するガスタービン用動翼において、前記翼部が

単結晶であり、前記ダブティルが一方方向凝固した柱状晶からなる一体の鋳物からなり、前記鋳物は重量で、C0.03~0.1%, Cr5.5~9.0%, Co8.5~10.5%, W8~11%, Re1.0~3.5%, Mo0.3~1.0%, Ta3~4%, Al5~6%, Ti0.5~1.0%, Hf0.5~1.0%, B及びZrの1種又は両者が0.005~0.025%、及び残部がNiと不可避不純物からなり、γ相マトリックス内にγ'相が析出した組織を有し、前記単結晶のγ相と柱状晶のγ相の結晶方位の差が8度以下であり、発電容量が5万KW以上であることを特徴とするガスタービン。

【請求項14】高速で流れる燃焼ガスによって駆動するガスタービンと、該ガスタービンの燃焼排ガスによって水蒸気を得る排熱回収ボイラと、前記水蒸気によって駆動する蒸気タービンと、前記ガスタービン及び蒸気タービンによって駆動する発電機とを備えた複合発電プラントシステムにおいて、前記ガスタービンは動翼を3段以上有し、前記燃焼ガスの前記動翼初段入口温度が1,300℃以上で、タービン出口の燃焼排ガス温度が560℃以上であり、前記排熱回収ボイラによって530℃以上の水蒸気を得、前記蒸気タービンは高低圧一体型であり、該蒸気タービン動翼の初段への前記蒸気温度が530℃以上であり、前記ガスタービンの発電容量が5万KW以上及び蒸気タービンの発電容量が3万KW以上であり、総合熱効率が45%以上であり、

前記動翼の初段は全長が200mm以上であり、前記動翼の初段は翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起

からなるフィンと、前記シャンク部に連なるダブティルとを有し、前記翼部が単結晶であり、前記ダブティルが一方方向凝固した柱状晶である一体の鋳物からなり、前記鋳物は重量で、C0.03~0.1%, Cr5.5~9.0%, Co8.5~10.5%, W8~11%, Re1.0~3.5%, Mo0.3~1.0%, Ta3~4%, Al5~6%, Ti0.5~1.0%, Hf0.5~1.0%, B及びZrの1種又は両者が0.005~0.025%、及び残部がNiと不可避不純物からなり、γ相マトリックス内にγ'相が析出した組織を有し、前記単結晶のγ相と柱状晶のγ相の結晶方位の差が8度以下であることを特徴とする複合発電プラントシステム。

【請求項15】翼部と、該翼部に連なる付根部とを有し、一体の鋳物からなるガスタービン用動翼の製造法において、該動翼を形成する鋳型を水冷チルプレート上にセットする工程と、前記鋳型を加熱炉内にセットし鋳型を所定温度に加熱する工程と、鋳造原料を真空溶解後前記加熱された鋳型内に溶湯を鋳込む工程と、該溶湯を有する鋳型を前記加熱炉から相対的に引き抜いて前記翼部先端から前記付根部側末端にかけて順次凝固させて前記翼部を単結晶とした後該翼部の鋳型の引き出し速度より早い速度で引き抜いて前記付根部を一方方向凝固し柱状晶とする工程とを有することを特徴とするガスタービン用動翼の製造法。

【請求項16】単結晶と柱状晶との一体の一方方向凝固鋳物からなり、前記単結晶と柱状晶との前記凝固方向に対して直角方向における結晶方位の差が8度以下であることを特徴とする物品。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は新規なガスタービン用動翼に係り、特にクリープ強度に優れた動翼とその製造法及びそれを用いたガスタービンに関する。

【0002】

【従来の技術】発電用ガスタービンの動翼材料は、従来から主としてNi基の超合金が使用されてきたが、ガスタービンの熱効率向上を図るため、年々燃焼ガス温度が上昇してきた。そして、それに伴い動翼の耐熱強度を上げるため、組織的には普通鋳造による等軸晶翼から一方方向凝固による柱状晶翼へと変化すると共に、翼内部に複雑な冷却孔を設け、内部からの冷却を図ってきた。

【0003】柱状晶鋳物の大部分は、特公昭51-4186号等で示されている一方方向凝固法で製造されている。この方法は、加熱した炉の中から鋳型を下方に引出し、下端から上方に漸次凝固させる方法である。この方法により、遠心応力が作用する長手方向に長く伸び、〈100〉方位の結晶方位を有する柱状晶動翼が製造され、クリープ強度特性や熱疲労強度特性が改善されてきた。

【0004】また、柱状晶動翼より高温特性に優れた動翼として特開昭60-261659号公報及び特開昭61-71168

号公報には翼部を単結晶とし、付根部を微結晶とした燃焼タービン用羽根の製造法が開示されている。

【0005】

【発明が解決しようとする課題】更に高効率化を図るためには、燃焼ガス温度を高めることが最も有効な方法であり、そしてそのためには内部冷却をさらに強化すると共に、材料の高温強度を高めることが必要になってきた。

【0006】ガスタービン用動翼の内部冷却孔は、セラミック中子を用いて形成されるが、冷却を更に強化するため、冷却用パスの数を多くすると共に、翼自体の薄肉化が図られてきた。柱状晶動翼は一方凝固法で製造されているが、熔融金属は中子を鑄ぐるんだ状態で凝固し、その後室温まで冷却される。そして、冷却時には熱収縮を生じる。中子と鑄造金属の熱膨張係数を比較すると、中子は金属より一桁程度小さい値を示すため、金属はほとんど収縮しない中子を内部に鑄ぐるんだまま収縮することになり、冷却の過程で大きな引っ張り応力が発生してくることになる。このため鑄造品は、強度の弱い結晶粒界に沿って縦割れが発生しやすくなる。そして、縦割れは特に薄肉部である翼部で著しい。その為、従来の柱状晶動翼は翼部の薄肉化ができず、冷却を充分に行うことができなかった。また鑄造時に粒界割れが発生し歩留まりも悪かった。

【0007】航空機用ジェットエンジンに用いられている動翼は、翼長が最大でも10cm程度、重さも数百グラムであり単結晶化は容易である。しかし、発電用ガスタービンに用いられる動翼は、翼の形状が複雑であるばかりでなく、翼長は15~40cm、重さも数kgから10kg程度と非常に大きくなるため、特公昭51-4186号公報でのやり方では異結晶やフレックル欠陥などが発生しやすく単結晶化は非常に困難になっている。

【0008】特開昭60-261659号公報及び特開昭61-71168号公報には、翼部を単結晶、残りの部分を磁気攪拌を利用して微小結晶粒とする製造法が述べられている。しかし、この方法で従来の単結晶合金を鑄造すると微小結晶粒部分の強度が弱くなる問題があった。また、微小結晶粒部分の強度を保つために、多量の粒界強化元素を含んだ合金を用いて鑄造すると、凝固時に形成された共晶組織及び共晶 γ' 相の融点が低下するため溶体化が十分できず、結果的に材料の強度向上を図れなかった。

【0009】以上述べたように、従来技術による動翼では、冷却効率の向上を図るために薄肉化すると粒界割れが発生しやすくなり、また粒界割れを防止するために粒界強化元素を添加すると強度向上がはかれないという欠点があり、ガスタービンの効率向上を図ることが出来なかった。

【0010】また、高温強度に優れた単結晶動翼は、異結晶が発生しやすいため歩留まりが非常に悪く、また大きな物は製造できないため、発電用ガスタービンの動翼

としては適用できず、ガスタービンの効率向上を図ることができなかった。

【0011】本発明の目的は、鑄造時の粒界割れがなく、しかもクリープ強度に優れたガスタービン用柱状晶動翼及びその製造法とそれを用いたガスタービンを提供することにある。

【0012】

【課題を解決するための手段】本発明は、高温高压ガスにさらされる翼部と、該翼部に連なり高温高压ガスを遮断するための張出し部であるプラットフォームと、該プラットフォームに連なり該翼部とディスクの間に充分な温度勾配を得るための距離を有するシャンク部と、該シャンク部に設けられた高温高压ガスを遮断するための突起であるシールフィンと、該シャンク部に連なるディスクへの埋込部であるダブティルとを有し、前記翼部は少なくともその外面が単結晶であり、翼部内部を含み翼部からシャンク部の1部に連続して形成された単結晶を有し、残部が該単結晶から連続して形成された一方凝固した柱状晶からなる一体の鑄物からなるガスタービン用動翼である。

【0013】即ち、本発明に係るガスタービン用動翼は、翼部が単結晶であり、残りが一方凝固柱状晶からなるものであるが、残りのプラットフォーム及びシャンク部内に翼部からの単結晶が引き続き形成される。

【0014】特に、本発明に係るガスタービン用動翼は、多結晶部を柱状晶組織として柱状晶の長手方向の方位は〈100〉方位から15度以内であり、隣接する柱状晶の結晶方位差を15度、特に8度以内とすることが好ましい。

【0015】また、翼部の単結晶における結晶方位差が8度以内なら特に粒界は見られず許容することができる。

【0016】特に、翼部外面の隣接する結晶粒間の方位差が8度以内であり、該翼部外面以外の該翼部内部を含む部分の一部の隣接する結晶粒間の方位差が8度以内、残部の隣接する結晶粒間の方位差を15度以内とすることが好ましい。

【0017】さらに、翼部とその他の部分の結晶粒の最大の結晶方位の差は8~15度以内であることが好ましい。

【0018】また、上記のガスタービン動翼を得るためには、単結晶の少なくとも1ヶ所と突起であるシールフィンの間に凝固促進通路を設けることが有効である。

【0019】本発明のガスタービン動翼には、ダブティルから翼部にかけて、内部に動翼を冷却するための冷媒通路が設けられることがある。

【0020】本発明のガスタービン動翼には、翼部表面に、Cr、Al、Yを含むCoまたはNiを主成分とする合金層をコーティングすることがある。

【0021】さらに、本発明のガスタービン動翼は、前

記翼部及びその周辺の最外表面に、セラミックス層からなる遮熱コーティングを有する場合がある。

【0022】本発明に係るガスタービン用動翼は、重量で0.03%以上のC、0.005%以上のB及び0.005%以上のZrの一種又は二種以上の元素を含み、且つ合金の粒界での、局所的な溶融による初期溶融を生じること無く、析出 γ' 相を γ 相中に固溶できるNi基超合金で製造されているものである。

【0023】特に、C0.05~0.1%、B及びZrの1種又は2種を0.005~0.025%より好ましくはB0.002~0.02%、Zr0.02%以下とするのが割れを防止するのに好適である。

【0024】本発明に係るガスタービン用動翼は重量%で、以下の好適な組成のNi基超合金で製造されているものである。

【0025】鋳物は重量%で、C0~0.20%、Cr2~16%、Al4~7%、W2~15%、Ti0.5~5%、Nb0~3%、Mo0~6%、Ta0~12%、Co0~10.5%、Hf0~2%、Re0~4%、B0~0.035%、Zr0~0.035%、及び20残部が58%以上のNiからなる。

【0026】本発明は、翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有するガスタービン用動翼において、前記翼部が単結晶であり、前記翼部及び前記フィンを除いた部分が一方凝固した柱状晶である一体の鋳物からなることを特徴とする。

【0027】本発明は、翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有するガスタービン動翼において、前記翼部が単結晶であり、前記翼部以外の全部が一方凝固した柱状晶である一体の鋳物からなることを特徴とする。

【0028】本発明における動翼は内部に一体に連なる冷媒通路を有する。

【0029】本発明は、重量で、C0~0.20%、Cr2~16%、Al4~7%、W2~15%、Ti0.5~5%、Nb0~3%、Mo0~6%、Ta0~12%、Co0~10.5%、Hf0~2%、Re0~4%、B0~0.035%、Zr0~0.035%、及び40残部が58%以上のNiからなり、前記C量とB及びZr量的一方又は両方がA(C0.20%、B+Zr0%)、B(C0.05%、B+Zr0%)、C(C0%、B+Zr0.01%)、D(C0%、B+Zr0.035%)及びE(C0.1%、B+Zr0.025%)の範囲内にあり、結晶方位の差が2~8度であることを特徴とするガスタービン用動翼にある。

【0030】本発明は、重量で、C0.03~0.1%、Cr5.5~7.0%、Co8.5~9.5%、W8~9%、Re2.5~3.5%、Mo0.3~1.0%、Ta3~4%、Al5~6%、Ti0.5~1.0%、Hf0.5~1.0%、B及びZrの1種又は両者が0.005~0.025%、及び残部がNiと不可避不純物であり、結晶方位の差が8度以下であることを特徴とするガスタービン用動翼にある。

【0031】本発明の動翼は3段又は4段のガスタービンのいずれの段に用いられるが、特に最も温度の高い初段に好適である。2段以降は特に全体を柱状晶又は等軸晶とした多結晶のものが好適である。

【0032】特に、以下の組成が好適である(重量%)。

【0033】

C : 0.03~0.1	Cr : 5.5~7.0
Co : 9~10.5	W : 8.0~11.0
Re : 1.0~3.5	Mo : 0.3~1.0
Ta : 3.0~4.0	Al : 5.0~6.0
Ti : 0.5~1.0	Hf : 0.5~1.0
B及びZrの1種又は2種 : 0.005~0.025	

残部 : Ni及び不可避不純物

また、本発明に係るガスタービン用動翼は、製造後合金の γ' 相の固溶温度以上、初期溶融温度以下の温度範囲で2~60時間溶体化され、更に1000~1150℃で4~20時間及び800~920℃で8~100時間熱処理を施すのが好適である。

【0034】また、本発明に係るガスタービン用動翼の製造法は、セラミック中子を有する鋳型を水冷チルプレート上にセットする工程と、鋳造原料を溶解後加熱された鋳型内に溶湯を鋳込む工程と、鋳型を高温の加熱炉から相対的に引き抜いて、翼部先端側から付根部側へ漸次一方凝固させて翼部を単結晶とする工程と、該翼部の鋳型の引出し速度より早い速度で引き抜いて付根部を一方凝固させることを特徴とするガスタービン動翼の製造法にある。

【0035】単結晶製造における鋳型移動速度を15cm/h以下とすることが好ましく、柱状晶製造における移動速度を20~45cm/hとすることが好ましく、特に、前者は単結晶製造できるものであれば早いほどよいが、歩留りの点から、10cm/h程度が好ましく、後者は50cm/hを超えると柱状晶間の結晶方位が10度を超えまた等軸晶となるので、45cm/h以下がよく、8度以下とするには早い速度の方がよいので、30~45cm/hが好ましい。

【0036】本発明は、単結晶と柱状晶との一体の一方凝固鋳物からなり、前記単結晶と柱状晶との前記凝固方向に対して直角方向における結晶方位の差が8度以下であることを特徴とする物品にあり、ガスタービン用動翼以外に使用できる。

【0037】本発明は、翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有するガスタービン動翼において、前記翼部が単結晶であり、前記翼部以外の全部が一方向凝固した柱状晶である一体の鋳物であり、前記ダブティル部から翼部先端にかけて内部に一体に連なる冷媒通路が設けられ、前記鋳物は重量で、C 0.03～0.1%、Cr 2～16%、Al 4～7%、W 2～15%、Ti 0.5～5%、Nb 0～3%、Mo 0～6%、Ta 0～12%、Co 0～10.5%、Hf 0～2%、Re 0～4%、B 0～0.035%、Zr 0～0.035%、及び残部が58%以上のNiからなり、前記C量とB及びZr量の一方又は両方ともA(C 0.20%、B+Zr 0%)、B(C 0.03%、B+Zr 0%)、C(C 0%、B+Zr 0.01%)、D(C 0%、B+Zr 0.035%)及びE(C 0.1%、B+Zr 0.025%)の範囲内にあり、 γ 相マトリックス内に γ' 相が分散した組織を有し、前記 γ 相の結晶方位の差が2～6度であることを特徴とする。

【0038】本発明は、コンプレッサによって圧縮された燃焼ガスを静翼を通してディスクに植設された動翼に衝突させて該動翼を回転させるガスタービンにおいて、前記動翼を3段以上有し、該動翼の初段が翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンクと、該シャンクの両側に設けられた突起からなるフィンと、前記シャンクに連なるダブティルとを有し、前記翼部が単結晶であり、前記翼部及び前記フィン以外の全部が一方向凝固した柱状晶である一体の鋳物からなることを特徴とするガスタービン。

【0039】本発明は上述のガスタービンにおいて、前記燃焼ガス温度が1,500℃以上であり、前記動翼を3段以上有し、該動翼の初段入口での前記燃焼ガス温度が1,300℃以上であり、前記動翼の初段は全長が200mm以上で、その翼部が単結晶であり、該翼部を除く付根部が一方向凝固した柱状晶である一体の鋳物からなり、発電容量が5万KW以上であることを特徴とする。

【0040】本発明は、コンプレッサによって圧縮された燃焼ガスを静翼を通してディスクに植設された動翼に衝突させて該動翼を回転させるガスタービンにおいて、前記燃焼ガス温度が1,500℃以上であり、前記動翼を3段以上有し、該動翼の初段入口での前記燃焼ガス温度が1,300℃以上であり、前記動翼の初段は全長が200mm以上で、前記動翼の初段は翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有するガスタービン用動翼にお

いて、前記翼部が単結晶であり、前記フィンを除き一方向凝固した柱状晶である一体の鋳物からなり、前記鋳物は重量で、C 0.03～0.1%、Cr 5.5～9.0%、Co 8.5～10.5%、W 8～11%、Re 1.0～3.5%、Mo 0.3～1.0%、Ta 3～4%、Al 5～6%、Ti 0.5～1.0%、Hf 0.5～1.0%、B及びZrの1種又は両者が0.005～0.025%、及び残部がNiと不可避不純物からなり、 γ 相マトリックス内に γ' 相が析出した組織を有し、前記単結晶の γ 相と柱状晶の γ 相の結晶方位の差が8度以下であり、発電容量が5万KW以上であることを特徴とする。

【0041】本発明は、高速で流れる燃焼ガスによって駆動するガスタービンと、該ガスタービンの燃焼排ガスによって水蒸気を得る排熱回収ボイラと、前記水蒸気によって駆動する蒸気タービンと、前記ガスタービン及び蒸気タービンによって駆動する発電機とを備えた複合発電プラントシステムにおいて、前記ガスタービンは動翼を3段以上有し、前記燃焼ガスの前記動翼初段入口温度が1,300℃以上で、タービン出口の燃焼排ガス温度が560℃以上であり、前記排熱回収ボイラによって530℃以上の水蒸気を得、前記蒸気タービンは高低圧一体型であり、該蒸気タービン動翼の初段への前記蒸気温度が530℃以上であり、前記ガスタービンの発電容量が5万KW以上及び蒸気タービンの発電容量が3万KW以上であり、総合熱効率が45%以上であることを特徴とする。

【0042】高速で流れる燃焼ガスによって駆動するガスタービンと、該ガスタービンの燃焼排ガスによって水蒸気を得る排熱回収ボイラと、前記水蒸気によって駆動する蒸気タービンと、前記ガスタービン及び蒸気タービンによって駆動する発電機とを備えた複合発電プラントシステムにおいて、前記ガスタービンは動翼が3段以上有し、前記燃焼ガスの前記動翼初段入口温度が1,300℃以上で、タービン出口の燃焼排ガス温度が560℃以上であり、前記排熱回収ボイラによって530℃以上の水蒸気を得、前記蒸気タービンは高低圧一体型であり、該蒸気タービン動翼の初段への前記蒸気温度が530℃以上であり、前記ガスタービンの発電容量が5万KW以上及び蒸気タービンの発電容量が3万KW以上であり、総合熱効率が45%以上であり、前記動翼の初段は全長が200mm以上であり、前記動翼の初段は翼部と、該翼部に連なる平坦部を有するプラットフォームと、該プラットフォームに連なるシャンク部と、該シャンク部の両側に設けられた突起からなるフィンと、前記シャンク部に連なるダブティルとを有し、前記翼部が単結晶であり、前記フィンを除き一方向凝固した柱状晶である一体の鋳物からなり、前記鋳物は重量で、C 0.03～0.1%、Cr 5.5～9.0%、Co 8.5～10.5%、W 8～11%、Re 1.0～3.5%、Mo 0.3～1.0%、Ta 3～4%、Al 5～6%、Ti 0.5～

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1.0%, Hf 0.5~1.0%, B及びZrの1種又は両者が0.005~0.025%、及び残部がNiと不可避不純物からなり、 γ 相マトリックス内に γ' 相が析出した組織を有し、前記単結晶の γ 相と柱状晶の γ 相の結晶方位の差が8度以下であることを特徴とする。

【0043】本発明に係るガスタービン用動翼は、重量%で0.20%以下のC、0.002~0.02%のB、0.002%以上のZr及び0.5%以上のHfの一種又は二種以上の元素を含み、且つ局部的熔融による初期熔融を体積率で約5%以上生じることなく、体積率で約60%以上の析出 γ' 相を γ 相中に固溶できるNi基超合金で鍛造されているものである。

【0044】特に、C 0.03~0.1%, B及びZrの一種又は二種を0.002~0.20%およびHfを0.5~1.1%とするのが割れを防止し、且つ初期熔融を、体積率で約5%以上生じることなく、体積率で約60%以上の析出 γ' 相を γ 相中に固溶させるために好適であり、前記C量とB+Zr量をA(C 0.20%, B+Zr 0%), F(C 0.04%, B+Zr 0.002%), C(C 0%, B+Zr 0.01%), G(C 0%, B+Zr 0.02%), H(C 0.10%, B+Zr 0.20%)の範囲にすることが好ましい。

【0045】鍛造時の粒界割れ、クリープ強度、耐食性、耐酸化性及び耐熱疲労特性などのすべてを満足するためには、特に、Cr 6.0~9.0%, Al 5~6%, W 7~10%, Ti 0.5~1%, Mo 0.3~0.7%, Ta 3.0~7.0%, Re 1~3.4%, Co 8~10.5%, C 0.03~0.1%, B 0.002~0.02%, Hf 0.5~1.1%, Zr 0.02% 以下、及び残部がNiと不可避不純物である組成が好適である。

【0046】また、本発明の動翼は、タービンを三段又は四段有するガスタービンのいずれのタービンにも用いることができるが、特に最もメタル温度が高くなる初段タービンに好適である。二段目以後には、全体を柱状晶又は等軸晶としたものが用いられることが多い。

【0047】本発明のガスタービン用動翼は、鍛造後合金の析出 γ' 相の固溶温度以上、初期熔融温度以下の範囲で2~60時間溶体化され、更に1000~1150%で4~20時間及び800~920℃で8~100時間熱処理を施すのが好適である。

【0048】また、本発明のガスタービン用動翼は、該動翼を形成するための鋳型を水冷チルプレート上にセットする工程と、前記鋳型を真空の加熱炉内で所定の温度に加熱する工程と、鍛造原料を鋳型と同一の真空チャンパー内で溶解して前記の加熱された鋳型に溶湯を鋳込む工程と、該溶湯を含む鋳型を前記加熱炉から引き抜いて、前記翼部からダブティルの方向に順次方向凝固させて前記翼部を単結晶とした後、前記ブラットフォーム以降を前記翼部の引き出し速度より早い速度で引き抜いて、前記翼部以外の部分の一部を該翼部から連続して

方向凝固した単結晶、残部を該単結晶から連続して一方方向凝固した柱状晶である一体の鋳物とする工程により製造される。

【0049】上記の鋳型引き出し速度は、単結晶製造においては15cm/h以下とすることが好ましく、柱状晶製造においては20~45cm/hとすることが好ましい。これらは、それぞれ製造が可能であれば早いほど良いが、歩留りの点から、単結晶製造については10cm/h程度が好ましい。柱状晶については、50cm/hを超えると柱状晶間の結晶方位の差が20度を超えさらに等軸晶となるので、45cm/h以下が良く、また、隣接する柱状晶間の結晶方位差が15度以下の良好な柱状晶を得るためには、引き出し速度が遅すぎるのものが好ましくなく、好適には、30~45cm/hである。

【0050】

【作用】本発明に係るガスタービン用動翼は、翼部を単結晶とし、単結晶における結晶方位差を8度以内とするものである。そして、翼部以外を一方方向凝固柱状晶とし、隣接する柱状晶どうしの結晶方位差をできるだけ小さくし、特にその差を15度以内、より好ましくは8度以内とすることにより結晶粒界強化元素の添加量を少なくしても、鍛造時の粒界割れが発生しない柱状晶翼とすることができ、単結晶と同等の強度を維持することができる。また、結晶粒界強化元素の添加量を少なくしたため、鍛造時に形成される共晶組織の融点が上昇し、溶体化熱処理温度を上げることが出来るため、析出 γ' 相を母相の γ 相中に固溶させる熱処理が可能となった。そのため、高クリープ強度を有する柱状晶翼とすることができる。逆に、結晶方位の差が10度を超えると単結晶の強度の10~20%程度と急激に低下してしまう。

【0051】材料の高温強度を向上させるためには、鍛造後の溶体化熱処理が有効である。溶体化熱処理は、凝固後析出した γ' 相を母相中に完全に固溶させることによりその後の時効熱処理で析出 γ' 相の大きさや形状を最適化でき、高温強度を向上させることができる。

【0052】しかし、従来の柱状晶動翼に用いられている合金は、鍛造時の結晶粒界に沿った縦割れを防止するため、B、C、Zr、Hf等の結晶粒界強化元素を多く含有させる必要がある。結晶粒界強化元素は結晶粒界の強度を向上させると共に、一部はデンドライトアーム間に偏析し、偏析部の融点を著しく低下させる。Ni基超合金の場合、前記偏析部は共晶組織を形成し、凝固時に粗大な共晶 γ' 相を生じる。この時形成され共晶組織及び共晶 γ' 相は合金中で最も融点が低く、溶体化熱処理を行うために温度を上げると共晶組織が初期熔融を生じてくる。そのため、従来の柱状晶動翼に用いられている合金は溶体化熱処理温度を高くできず、溶体化が不十分であったため、結果的に材料の強度向上を図ることが出来なかった。

【0053】なお、結晶粒界強化元素を含まない単結晶

用合金は、結晶粒界強化元素を不純物元素として取り扱い、含有量を極力少なくしているため共晶 γ' 相の融点が増し、完全溶体化熱処理を可能にしている。そのため、単結晶合金は、従来の材料より、40～50℃高い優れた高温特性を示し、航空機用ジェットエンジンの動翼として使用される。しかし、単結晶合金は、結晶粒界強化元素を極力少なくしているため、結晶粒界が形成されと非常に弱く、結晶方位の異なる異結晶があると、その結晶粒界で容易に割れが入る。結晶粒界があると、通常は、鍛造後の冷却のみで割れが入る程度の弱さになる。そのため単結晶合金を用いて鍛造した動翼は異結晶のない完全な単結晶にする必要がある。

【0054】また、前記の粒界強化元素を含む合金で、動翼全体を単結晶とすることも当然可能である。この動翼は、結晶粒界強化元素を含まない単結晶専用合金で鍛造された単結晶翼と比べて高温でのクリープ強度は劣るが、高温になる翼部外面以外では隣接する結晶粒間の方位差を15度まで許容できるため、従来の単結晶翼で必要であったX線による結晶方位測定を大幅に簡略化できる。さらに、翼内部の結晶欠陥に対しては有効な検査手段が無く、通常は抜取り試験で翼を切断して検査している。しかし、翼が大型になる発電用ガスタービン用の動翼では、抜取り試験では信頼性の確保が難しく、単結晶翼を発電用ガスタービンに適用する上での大きなネックになっていた。しかし、本発明では隣接する結晶粒間の方位差を15度まで許容できるため、動翼の信頼性を大幅に向上でき、高強度動翼の発電用ガスタービンへの適用が可能となった。

【0055】ガスタービン用動翼を構成するNi基超合金に含有される各元素の役割を次に示す。

【0056】Cはマトリックスあるいは特に粒界に固溶すると共に炭化物を形成し高温引張強さを向上させるが、過剰に添加すると、粒界の融点を低め高温強度及び靱性を低下させるので添加量としては、0.20%以下、特に0.05～0.2%の範囲が適正であり、より0.03～0.1%が好ましい。

【0057】Coはマトリックス中に固溶して高温強度を向上させると共に、耐食性向上に寄与するが、過剰に添加すると有害な金属間化合物析出を助長し、高温強度の低下を招く。添加量としては、10.5%以下とし、特に8～10.5%が適正である。特に、下限として4%以上、より8.5%以上が好ましい。

【0058】Crは耐食性を改善するのであるが、過剰添加すると有害な σ 相析出や炭化物の粗大化を引起し、高温強度を低下させる。添加量としては2～16%、好ましくは5～14%の範囲が適正であり、特に5.5～9%の範囲が好ましい。

【0059】Al、TiはNi基合金の析出強化因子である γ' 相すなわちNi₃(Al、Ti)を析出させて高温強度の向上に寄与する。添加量としては、Al:4.

0～7.0、Ti:0.5～5.0%の範囲は適正であり、特にAl5～6%、Ti0.5～1.0%が好ましい。

【0060】Nb、Ta、Hfは強化因子である γ' 相に固溶され、高温強度を向上するが、過剰に添加すると、結晶粒界に偏析しかえって強度を低下させる。添加量としては、Nb3%以下、Ta12%以下、Hf2%以下が適正であり、特にNb:0.2～3.0%、Ta2～7%、より3～4%、Hf0.5～1.0%が好ましい。特に、Hfは凝固時の縦割れ防止の効果があり、高温での延性を改善させるが、2%を越えると凝固時の共晶組織を増大させ、有効な溶体化処理を困難にさせる。

【0061】Zr、Bは凝固時の縦割れを防止し、粒界を強化し、高温強度を改善するが、過剰に添加すると延性、靱性を低下し、粒界の融点を下げ高温強度を低下させる。添加量としては、Zr:0～0.035%、B:0～0.035%が適正である。特に、C量との関係からA(C0.20%、B+Zr0%)、B(C0.05%、B+Zr0%)、C(C0%、B+Zr0.01%)、D(C0%、B+Zr0.035%)、E(C0.1%、B+Zr0.025%)の範囲内、又はB及びZrの1種又は2種が0.005～0.025%が好ましい。より好ましくは、A、F、C、G、H及びAで囲まれた範囲が好ましい。

【0062】W、Moはマトリックスの γ 相に固溶して強化し、特に長時間強度の改善に効果が大きい。しかしながら、過剰に添加すると σ 相等の有害相析出を助長し、かえって強度を低下させる。添加量としては、W2～15%、Mo6.0%以下が適正であり、特にW7.0～11.0%、Mo0.3～1.0%が好ましい。よりW8～10%が好ましい。

【0063】Reは耐高温腐食性を向上させるが、ある程度の添加量以上になると効果が飽和し、かえって延性、靱性の低下を招く。添加量としては、Re4%以下、特に1～4%、より2.5～3.5%が好ましい。

【0064】

【実施例】

【実施例1】図1は本発明に係るガスタービン用単結晶動翼の斜視図を示し、図2は本発明の動翼の製造方法を示す装置の概略図である。

【0065】図2において、最初、冷水銅チルプレート11の上に、セットしたアルミナを主成分とするセラミック鑄型8を固定し、それを鑄型加熱炉4の中にセットし、セラミック鑄型8をNi基超合金の融点以上に加熱する。次に溶解したNi基超合金をセラミック鑄型8の中に鑄込み、その後水冷銅チルプレート11を下方に引出し、一方向凝固させた。一方向凝固では最初スタータ10で多くの結晶を発生させる。次にセレクトラ9で一つの結晶のみを成長させる。更に拡大部で結晶を大きくさせ、翼部を10cm/hの引出し速度で凝固することによ

り単結晶化する。翼部が凝固し単結晶化した後、プラットフォーム15で鋳型の引出し速度40cm/hと速くすることにより、残りの部分を単結晶成長せず柱状晶とした。この方法によって翼部は単結晶組織、翼部以外は柱状晶組織の柱状晶動翼が得られた。この場合、柱状晶は翼部の単結晶を種として成長させるため、柱状晶間の方位の差を約5度とすることができた。また、鋳型加熱炉4はセラミック鋳型8が完全に引出され、凝固が終了するまで高温に保った。また、上記溶解と凝固の工程は、全て真空中で行った。表1に単結晶動翼の鋳造条件及

※10
表 1

鋳型加熱温度	1540℃
鋳込み温度	1550℃
鋳型引出し速度	翼部：10cm/hプラットフォーム以降：40cm/h
鋳型材質	アルミナ系セラミック鋳型

【0067】

※ ※【表2】
表 2

C	0.05~0.1	Cr	5.5~7.0
Co	9.0~9.5	W	8.0~9.0
Re	2.8~3.1	Mo	0.3~0.7
Ta	3.0~4.0	Al	5.5~6.0
Ti	0.5~0.9	Hf	0.7~1.0
B	0.005~0.01	Zr	0.005~0.01
Ni	残 部	—	—

【0068】鋳型の引出し速度は鋳型8の中のプラットフォーム15に相当する部分に熱伝対を挿入し、その部分の温度を測定し凝固点になった時点で引出し速度を変えた。なお、加熱炉4の下部に黒鉛の仕切板を設けるとともに、その下部に水冷銅パイプを螺旋状に巻回して鋳型を冷却するようにした。

【0069】以上のやり方で得た動翼は翼部1は単結晶で、プラットフォーム15より下の部分2は柱状晶となった。空冷フィン14では柱状晶とは言い難い直径10mm程度の結晶粒となっていた。シャंक18の表面では柱状晶であったが、内部は翼部1の単結晶が成長した大きな柱状晶から次第に小さい柱状晶が形成された。表面での柱状晶の幅は5~10mmで、平均の幅は5~6mmであった。翼部はエッチングによって外表面において全単結晶であることが確認することができた。従って、翼部における結晶方位の差は8度以内であることが分る。

【0070】図3は動翼の中子の平面図で、動翼との位置関係を示したものである。本実施例における動翼は内部を冷却できるように空洞にする。冷却媒体として空気が用いられるが水蒸気冷却も適用できる。冷媒はダブル16の中子21の部分より供給され、翼先端の17より排出される部分と翼のトレーリングエッジ23より排出される部分とに分けて流れる。中子の20、22は

*び、表2に鋳造に用いたNi基超合金の化学組成を示す。尚、上記方法で鋳造した柱状晶動翼は、鋳造後1260~1280℃で真空中2~60h溶体化処理を行って、凝固後の冷却過程で形成された析出 γ' 相を γ 相に変え、その後1000~1150℃で4~20hと800~950℃で8~100hの時効熱処理を行い、マトリックスの γ 相中に平均0.3~2 μ mより好ましくは0.1~0.5 μ mの γ' 相を析出させた。

【0066】

【表1】

穴になっていて2枚の翼部が互いにこの穴に対応して形成される突起によって一体になっており、トレーリングエッジ23部分の冷媒の排出口はスリット状になっている。中子の22は穴になっていてこの部分に溶湯が埋められ一体になって形成される。

【0071】本実施例における翼部1の長さは約100mmで、プラットフォーム以降の長さが120mmの大きさを有する。

【0072】図4に得られた動翼のクリープラプチャー強度を、ラルソン・ミラーパラメータPを用いて示す。比較材は市販のCM186LC合金の柱状晶を用いた。単結晶化後溶体化熱処理及び時効熱処理を行うことによって、従来の柱状晶組織で時効熱処理のみを行ったものに比べ、応力14.0kgf/mm²、10万時間クリープでの耐用温度が約20℃向上した。市販合金組成は表2に示す合金組成において、B0.016%、Zr0.016%、C0.15%を有するものである。

【0073】〔実施例2〕本発明の動翼に溶体化熱処理を行えたのはC、B、Zr、Hfの添加量を制御し、共晶組織を融点を上昇させたためである。以下に共晶組織を融点を上昇させるための方法について述べる。

【0074】従来の粒界強化元素を含む合金は、C、B、Zr、Hf等を多く含んでおり、溶体化熱処理がで

きなかった。そこで、重量で、

Cr: 5.0~14.0% Co: 0~12.0%
W: 5.0~12.0% Re: 0~3.5%
Mo: 0.5~3.0% Ta: 3.0~7.0%
Al: 4.0~6.0% Ti: 0.5~3.0%
Hf: 0~2.0%

を含むNi基の合金について、合金のC量と(Zr+B)量の割合を変化させ、共晶組織の融点と析出 γ' 相の固溶温度の関係を調べた。その結果、C: 0.1%以下、B+Zr: 0.025%以下にすれば、共晶組織の初期溶融を生じることなく、析出 γ' 相を母相中に固溶できることが判った。しかし、C: 0.1%以下、B+Zr: 0.025%以下の組成範囲としたNi基超合金の一方凝固柱状晶翼を鋳造したところ、粒界割れが発生した。図5は従来の一方凝固で製造した柱状晶動翼の粒界割れのスケッチを示す。すなわち従来の一方凝固法で、C: 0.1重量%以下、B+Zr: 0.025重量%以下の合金を用いて柱状晶動翼を製造すると、粒界に割れが生じ、製品として使用できなかった。

【0075】そこで、柱状晶の結晶方位差と、合金のC量と(Zr+B)量、及び粒界割れの関係を調べたところ、柱状晶の結晶方位差が8度以内のときに、重量で、C: 0.03%以上、(Zr+B): 0.005%以上とすると、粒界割れのない健全な柱状晶翼が得られるが、柱状晶の結晶方位差が8度以上のときは、C: 0.03%以上、(Zr+B): 0.005%以上としても粒界割れが発生した。なお、C量が0.03%以下では柱状晶の*

表 3

翼の種類	鋳造温度 (℃)	鋳造時間 (h)	粒界割れ 率 (%)	欠陥発生 率 (%)	歩留り (%)	耐用温度 (℃)
柱状晶翼	1520	1.0	75	20	15	900
単結晶翼	1600	3.0	0	95	5	940
本発明	1540	1.5	0	30	70	920

【0079】本発明による柱状晶動翼は粒界割れが発生しないため、動翼の歩留り15%から70%と約5倍アップすると共に、応力14.0kgf/mm²、10万時間クリープでの耐用温度が約20℃上昇した。

【0080】耐用温度だけを比較すると単結晶よりも劣る。しかし、本発明では、翼部以外を柱状晶組織としたことで、鋳造時間を短くしかつ鋳型加熱温度を低くできた。その結果鋳型との反応が少なく、欠陥の割合が減少して、動翼の製造歩留まりが向上することから、本発明は極めて実用的な柱状晶動翼及び製造法である。なお、生産性及び歩留まりは劣るが、本合金を用いて翼全体を単結晶にしてもなら実害が無いことは自明である。

【0081】【実施例3】本発明の動翼に溶体化熱処理を行えたのはC、B、Zr、Hfの添加量を制御し、共晶組織を融点を上昇させたためである。以下に共晶組織の融点を上昇させるための方法について述べる。

* 結晶方位差が8度以内でも粒界割れが発生した。以上の結果をまとめて図6に示す。尚、結晶方位差を6度以内にすればA(C0.20%, B+Zr0%), B(C0.05%, B+Zr0%), C(C0%, B+Zr0.01%), D(C0%, B+Zr0.035%)及びE(C0.1%, B+Zr0.025%)内であれば初期溶融無く粒界割れもないものが得られる。

【0076】C: 0.1重量%以下、B+Zr: 0.025重量%以下の合金で粒界割れを発生させないためには、結晶方位の差を8度以内にすることが必要であるが、従来の一方凝固法は各柱状晶の横方向の結晶方位はランダムであり8度以内に制御することができなかった。しかし本発明の方法では翼部を単結晶とし、この単結晶を種にして柱状晶を成長させることにより、柱状晶の方位の差を8度以内とすることができた。すなわち本発明のように翼部を単結晶、翼部以外を方位差が8度以内の柱状晶とすることで、C: 0.1重量%以下、B+Zr: 0.025重量%以下でも粒界割れのない健全な柱状晶翼が得られた。BとZrは一方又は両方のいずれでも同じ効果を示した。

【0077】表3に翼長22cm(翼部100mm, 付根部120mm)の動翼を製造したときの従来法による柱状晶動翼、単結晶動翼及び本発明による動翼の特徴を比較して示す。尚柱状晶動翼及び単結晶動翼の鋳造には市販の合金を用いた。

【0078】

【表3】

【0082】従来の粒界強化元素を含む合金は、C、B、Zr、Hf等を多く含んでおり、溶体化熱処理ができなかった。そこで、重量で、

Cr: 2.0~16.0% Co: 4~10.5%
W: 2.0~15.0% Re: 0~4.0%
Mo: 0~6.0% Ta: 2.0~12.0%
Al: 4.0~7.0% Ti: 0.5~5.0%

を含むNi基の合金について、Hfが0.5~1.1%の範囲で合金のC量と(Zr+B)量の割合を変化させ、共晶組織の融点と析出 γ' 相の固溶温度の関係を調べた。その結果、B+Zr: 0.020%以下にすれば、共晶組織の初期溶融を生じることなく、析出 γ' 相を母相中に固溶できることが判った。しかし、Hf: 0.5~1.1%, C: 0.2%以下、B+Zr: 0.020%以下の組成範囲としたNi基超合金の一方凝固柱状晶翼を鋳造したところ、粒界割れが前述の図5に示すように発生

した。すなわち、Hf:0.5~1.1重量%, C:0.2重量%以下, B+Zr:0.020重量%以下の合金を用いて従来の一方向凝固法で結晶方位をランダムとした柱状晶動翼を製造すると、粒界に割れが生じ、製品として使用できなかった。

【0083】そこで、柱状晶の結晶方位差と、Hfが0.5%合金のC量と(Zr+B)量、及び粒界割れの関係を調べたところ、柱状晶の結晶方位差が15度以内のときに、重量で、C:0.03%以上、(Zr+B):0.002%以上とすると、粒界割れのない健全な柱状晶翼が得られるが、柱状晶の結晶方位差が15度以上のときは、C:0.03%以上、(Zr+B):0.002%以上としても粒界割れが発生した。なお、Zr+B量が0.002%未満では柱状晶の結晶方位差が15度以内でも粒界割れが発生した。

【0084】C量が0.1%以上では、1040℃、14 kgf/mm²のクリープ破断時間が400hに満たないものがあつた。また、初期溶融が起ることで完全な溶体化処理が行えないものは400hに満たなかつた。また、Hfが0.5~1.1%で柱状晶の結晶方位差が15度以内の場合のC量とZr+B量との関係がA(0.2%, 0%), F(0.04%, 0.002%), C(0%, 0.01%), G(0%, 0.02%), H(0.1%, 0.02%)の各点を囲んだ範囲内によつて得られる。

Hf : 0.5 ~ 1.1%, C : 0.2重量%以下, B + Zr : 0.020重量%以下の合金で粒界割れを発生させないためには、結晶方位の差を15度以内にすることが必要であるが、従来の一方向凝固法は各柱状晶の横方向の結晶方位はランダムであり15度以内に制御することができなかった。しかし本発明の方法では翼部を単結晶とし、この単結晶を種にして柱状晶を成長させることにより、柱状晶の方位の差を15度以内とすることができた。すなわち本発明のように翼部を単結晶、翼部以外を方位差が15度以内の柱状晶とすることで、Hf : 0.5 ~ 1.1重量%, C : 0.2重量%以下, B + Zr : 0.020重量%以下でも粒界割れのない健全な柱状晶翼が得られた。BとZrは一方又は両方のいずれでも同じ効果を示した。

【0085】表4に casting 条件及び合金組成（重量％）を示す。残部はNiである。

【0086】

【表 4】

表 4

[illegible]

クリーブ試験温度: 1040°C-1440°C/mm,

試薬片採取位置（クリープ試験機、3次元試験機）

主 発 行：集英社（東京都港区）※印はシヤンク印（社印）

林林总总：以图

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40 【0087】本発明動翼は粒界割れが発生しないため、従来の柱状晶動翼と比べて歩留りが15%から70%と約5倍アップすると共に、 $1040^{\circ}\text{C}-14\text{kgf}/\text{mm}^2$ の条件のクリープ破断時間が翼部で193hから456hと2倍以内向上した。また、本発明動翼のシャンク部は柱状晶であるが、溶体化処理を施すことで、柱状晶部のクリープ破断時間も従来柱状晶翼と比べて2倍以上であった。

【0088】本発明動翼と単結晶翼を比較すると、本発明動翼は高温クリープ強度では単結晶翼に劣っている。

50 しかし、本発明動翼は翼部以外を柱状晶とすることで、

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鑄造時間を短くしかつ鑄型加熱温度を低くすることができた。その結果、鑄型との反応及び中子の変形が少なくなり、欠陥の割合が減少して、製造歩留まりが向上したことから、本発明は極めて実用的な高強度動翼である。さらに、本発明動翼の柱状晶部の700℃付近での引張強度は単結晶翼と比べて約1割高かった。これは、柱状晶のサブグレインが引張強度の向上に寄与しているものと考えられるが、シャンク部に要求されるのは高温でのクリープ強度ではなく700℃付近の温度での引張強度であるため、翼部を単結晶、翼部以外を柱状晶とする本発明動翼は動翼に要求される2つの特性を兼ね備えた優れた動翼であるといえる。

【0089】[実施例4] 実施例1で述べた方法で表5に示す組成(重量%)のNi基超合金を鑄込み、翼部が単結晶、翼部以外をほぼ完全に柱状晶とした柱状晶動翼*

表 5

C	0.1~0.15	Cr	8.0~9.0
Co	9.5~10.5	W	10.0~11.0
Re	1.0~1.5	Mo	0.3~0.7
Ta	3.0~4.0	Al	5.5~6.0
Ti	0.5~1.5	Hf	0.7~1.0
B	0.005~0.01	Zr	0.005~0.01
Ni	残 部	—	

【0091】[実施例5] 実施例1で述べた方法で表6に示す合成を鑄込み、翼部が単結晶、翼部以外をほぼ完全に柱状晶としたガスタービン用動翼を鑄造した。本実施例における鑄型は図2において突起部であるフィンに対して単結晶拡大部よりバイパスさせたストレートな鑄型を凝固促進通路として追加し、フィンが良好な結晶性をもつ柱状晶になるようにした。その結果、この動翼には鑄造後に粒界割れは見られず、フィンは方位差5度以内の健全な柱状晶であった。

【0092】鑄造後、この動翼に、1250~1285℃-2~60hの溶体化熱処理及び1080℃-4hと871℃-20hの時効熱処理を施した試料と、1080℃-4hと871℃-20hの時効熱処理のみの試料を用意した。その結果、溶体化熱処理を施した試料は時効熱処理のみの試料より、表4中のすべての合金で応力14kgf/mm²、10万時間クリープでの耐用温度が約15℃向上していた。

【0093】

【表6】

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*を製造した。本実施例における鑄型は図2において空冷フィン部の突出部に対して単結晶拡大部よりバイパスさせたストレートな鑄型を形成させて空冷フィン部が柱状晶になるようにした。鑄造後の動翼に粒界割れは見られなかった。また合金に、1270~1285℃で真空中2~60hの溶体化処理、及び1000~1150℃で4~20hと800~950℃で8~100hの時効熱処理を行った。そして、1000~1150℃で4~20hと800~950℃で8~100hの時効熱処理のみを施した試料と、応力14.0kgf/mm²、10万時間クリープでの耐用温度を比較したところ、耐用温度が約15℃上昇していた。本実施例において、柱状晶同志の結晶方位差は約5度であった。

【0090】

【表5】

表 6

(wt%)	Ni	Zr	B	Hf	Ti	Al	Ta	Mo	Re	W	Co	Cr	C
合金(A)	0.020	~0.020	0.02	0.5	0.6	5.3	6.1	0.3	2.7	6.0	9.1	6.2	0.03
合金(B)	0.020	~0.020	0.02	~1.1	~1.2	~5.8	~6.9	~0.7	~3.2	~6.6	~9.9	~6.8	~0.10
合金(C)	0.020	~0.020	0.002	0.5	0.6	5.3	5.6	0.1	~0.3	7.4	4.1	7.3	0.03
			~0.020	~1.1	~1.2	~5.8	~6.4	~0.7		~8.4	~4.9	~8.2	~0.10
			~0.020	0.5	0.4	5.2	2.9	0.2	~0.3	9.1	8.8	7.3	0.03
			~0.020	~1.35	~1.1	~5.7	~3.5	~0.6		~9.7	~9.5	~8.6	~0.10

【0094】 [実施例6] 表7に示す本発明合金を用い
て、実施例1に示した方法に準じてガスタービン用動翼
を製造した。ただし、ここではプラットフォーム15を
過ぎても鋳型引出し速度を変えず、全体を10cm/hの
鋳型引出し速度で製造した。製造後、実施例1と同様の
熱処理を施し、この動翼から2つの結晶粒をもつ数本の
ミニチュア試料を切り出し、2つの結晶粒の凝固方向に
直角方向の結晶方位の差とクリープ強度の関係を調べ
た。なお、試料は粒界に平行方向に採取した。また、単
結晶専用合金である特公平3-75619号に示された合金
を比較合金として評価した。比較合金についても本発明

合金と同一の製造条件で製造し、特公平3-75619号に
示された熱処理を施した後、試験に供した。結果を表8
に示す。この結果から、本発明合金の1040℃、14
kgf/mm²のクリープ強度は、結晶方位の差が15度以
内であれば結晶方位差にほとんど影響されない。これに
対して、単結晶専用である比較合金は僅かの結晶方位の
差も許容できないことがわかる。

【0095】

【表7】

表 7

(wt%)	Ni	Zr	B	Hf	Ti	Al	Ta	Mo	Re	W	Co	Cr	C
合金(A)	0.0025	0.0025	0.015	0.7	0.5	5.5	3.0	0.3	2.8	8.0	9.0	5.5	0.05
合金(B)	0.005	~0.005	~0.020	~0.8	~0.9	~6.0	~4.0	~0.7	~3.1	~9.0	~9.5	~7.0	~0.09
合金(C)	0.006	0.006	0.016	1.4	0.69	5.68	3.2	0.5	3.0	8.5	9.2	6.6	0.07

【0096】

【表8】

	試験片採取位置	結晶方位差	クリープ破断時間
本発明合金 No. 1	翼部	1度以下	456 h
	翼部	3度	447 h
	シャंक部	5度	438 h
	シャंक部	7度	441 h
本発明合金 No. 2	翼部	1度以下	446 h
	翼部	7度	437 h
	シャंक部	12度	422 h
	シャंक部	15度	418 h
比較合金 No. 1	翼部	1度以下	436 h
	翼部	3度	433 h
	シャंक部	5度	427 h
	シャंक部	7度	411 h
比較合金 No. 2	翼部	1度以下	446 h
	翼部	7度	205 h
	シャंक部	8度	198 h
	シャंक部	12度	0.5 h

【0097】〔実施例7〕図7は実施例2の本発明のガスタービン動翼を有するガスタービンの回転部分の断面図である。

【0098】30はタービンスタブシャフト、33はタービン動翼、43はタービンスタッキングボルト、38はタービンスペーサ、49はディスタントピース、40はノズル、36はコンプレッサディスク、37はコンプレッサブレード、38はコンプレッサスタッキングボルト、39はコンプレッサスタブシャフト、34はタービンディスク、41は穴である。本発明のガスタービンはコンプレッサディスク36が17段あり、又タービン動翼33が3段のものである。タービン動翼33は4段の場合もあり、いずれにも本発明の合金が適用できる。

【0099】本実施例におけるガスタービンは、主な形式がヘビーチューティ形、一軸形、水平分割ケーシング、スタッキング式ロータからなり、圧縮機が17段軸流形、タービンが3段インパルス形、1、2段空気冷却による静動翼、燃焼器がバースフロー形、16缶、スロットクール方式を有するものである。

【0100】ディスタントピース39、タービンディスク34、スペーサ38、スタッキングボルト33を重量で、C0.06~0.15%、Si1%以下、Mn1.5%以下、Cr9.5~12.5%、Ni1.5~2.5%、Mo1.5~3.0%、V0.1~0.3%、Nb0.03~0.15%、N0.04~0.15%、残部Feからなる全焼戻しマルテンサイト鋼が用いられる。本実施例における特性として、引張強さが90~120kg/mm²、0.2%耐力70~90kg/mm²、伸び率10~25%、絞り率50~70%、Vノッチ衝撃値5~9.5kg-m/cm²、450℃10⁵hクリープ破断強度45~55kg/mm²であった。

【0101】タービン動翼33は3段有し、初段に実施例1で製造したものを用い、圧縮機の圧縮圧を14.7、温度400℃、初段動翼入口温度を1,300℃、燃焼器による燃焼ガス温度を1450℃級とした。また、タービン動翼33の2段目には同等の合金組成の多結晶体からなる翼長280mm(翼部160mm、プラットフォーム部以降長さ120mm)及び、第3段目を同じく同等の合金組成を用い、同じく多結晶体の翼長350mm(翼部230mm、他120mm)の中実翼を製造した。製法は従来のロストワックス法による精密鑄造法によった。

【0102】タービンノズル40には既知のCo基合金が用いられ、初段から3段までを真空精密鑄造によって翼部1ヶからなるものを形成されたものを用いる。翼部の長さは動翼の長さに相当する長さを有し、ピンフィン冷却、インピンジメント冷却及びフィルム冷却構造を有する。1段ノズルはサイドウォール両端で拘束されるが、2段目及び3段目はサイドウォール外周側の片側で拘束される。ガスタービンにはインタークーラーが設けられる。

【0103】本実施例によって得られる発電出力は50MWが得られ、その熱効率33%以上の高いものが得られる。

【0104】〔実施例8〕図8は実施例7のガスタービンを用い、蒸気タービンと併用した一軸型コンバインドサイクル発電システムを示す概略図である。

【0105】ガスタービンを利用して発電を行う場合、近年では液化天然ガス(LNG)を燃料としてガスタービンを駆動するとともにガスタービンの排ガスエネルギーを回収して得た水蒸気で蒸気タービンを駆動し、この蒸気タービンとガスタービンとで発電機を駆動するよう

にした、いわゆる複合発電方式を採用する傾向にある。この複合発電方式において以下のシステム構成によって従来の蒸気タービン単独の場合の熱効率40%に比べ約45%以上の高熱効率が可能となる。このような複合発電プラントにおいて、最近ではさらに、液化天然ガス(LNG)専焼から液化石油ガス(LPG)との両用を図ったり、LNG、LPGの混焼の実現によって、プラント運用の円滑化、経済性の向上を図ろうとするものである。

【0106】まず空気は吸気フィルタと吸気サイレンを10 通ってガスタービンの空気圧縮機に入り空気圧縮機は、空気を圧縮し圧縮空気を低NO_x燃焼器へ送る。そして、燃焼器では、この圧縮空気の中に燃料が噴射され燃焼して1400℃以上の高温ガスを作りこの高温ガスは、タービンで仕事をし動力が発生する。

【0107】タービンから排出された530℃以上の排気は、排気消音装置を通して排熱回収ボイラへ送られ、ガスタービン排気中の熱エネルギーを回収して530℃以上の高圧水蒸気を発生する。このボイラには乾式アンモニア接触還元による脱硝装置が設けられている。排ガスは3脚集合型の数百mもある煙突から外部に排出される。発生した高圧および低圧の蒸気は高低圧一体ロータからなる蒸気タービンに送られる。

【0108】また、蒸気タービンを出た蒸気は、復水器に流入し、真空脱気されて復水になり、復水は、復水ポンプで昇圧され給水となってボイラへ送られる。そして、ガスタービンと蒸気タービンは夫々、発電機をその両軸端から駆動して、発電が行われる。このような複合発電に用いられるガスタービン翼の冷却には、冷却媒体として空気の他に蒸気タービンで利用される蒸気を用い30 こともある。一般には翼の冷却媒体としては空気が用いられているが、蒸気は空気と比較して比熱が格段に大きく、また重量が軽いため冷却効果は大きい。

【0109】このコンバインド発電システムによりガスタービンが5万KW、蒸気タービンにより3万KWのトータルで8万KWの発電を得ることができ、本実施例における蒸気タービンはコンパクトとなるので、大型蒸気タービンに比べ同じ発電容量に対し経済的に製造可能となり、発電量の変動に対して経済的に運転できる大きなメリットが得られる。

【0110】本発明に係る蒸気タービンには高低圧一体型蒸気タービンとし、この高低圧一体型蒸気タービンの主蒸気入口部の蒸気圧力100atg、温度538℃に上昇させることによりタービンの単機出力の増加を図ることができる。単機出力の増加は、最終段動翼の翼長を30インチ以上に増大し、蒸気流量を増す必要がある。本発明に係る蒸気タービンは高低圧一体型ロータシャフトに植設されたブレードが13段以上備えており、蒸気は蒸気コントロールバルブを通して蒸気入口より前述の如く538℃、88atgの高温高圧で流入する。蒸気は入

口より一方向に流れ、蒸気温度33℃、722mmHgとなって最終段のブレードより出口より排出される。本発明に係る高低圧一体型ロータシャフトはNi-Cr-Mo-V低合金鋼の鍛鋼が用いられる。ロータシャフトのブレードの植込み部はディスク状になっており、ロータシャフトより一体に切削されて製造される。ディスク部の長さはブレードの長さが短いほど長くなり、振動を少なくするようになっている。

【0111】本実施例に係る高低圧一体型ロータシャフトはC0.18~0.30%, Si0.1%以下, Mo0.3%以下, Ni1.0~2.0%, Cr1.0~1.7%, Mo1.0~2.0%, V0.20~0.3%, 残部Feよりなり、900~1050℃で水噴霧冷却によって焼入れ後、650~680℃で焼戻しが施される。

【0112】プラントの構成は、ガスタービン、排熱回収ボイラ、蒸気タービン、発電機各1基からなる1組の発電システムを6組組み合わせた1軸型に配列するもののほか、ガスタービン1基に対し発電機1基組み合わせ、これらを6組組み合わせた後の排ガスによって蒸気を得、1台の蒸気タービンと1台の発電機とする多軸型とすることができる。

【0113】複合発電は、起動停止が短時間で容易なガスタービンと小型で単純な蒸気タービンの組み合わせで成立っており、このため、出力調整が容易に出来、需要の変化に即応した中間負荷火力として最適である。

【0114】ガスタービンの信頼性は、最近の技術の発展により飛躍的に増大しており、また、複合発電プラントは、小容量機の組み合わせでシステムを構成しているため、万一故障が発生してもその影響を局部にとどめることが出来、信頼性の高い電源である。

【0115】

【発明の効果】本発明によれば、高クリープ強度を有するガスタービン用動翼が得られるため、動翼の長寿命化と燃焼ガス温度の上昇によるガスタービン及びそれを用いた複合発電プラントシステムの熱効率向上を図る顕著な効果がある。

【0116】また、本発明によるガスタービン用動翼の製造法によれば、動翼製造における歩留まり率が向上できる。

40 【図面の簡単な説明】

【図1】本発明に係るガスタービン用動翼の斜視図である。

【図2】本発明に係るガスタービン用動翼の製造法の概略を示す構成図である。

【図3】本実施例に示す中子の平面図と動翼との位置関係を示す図である。

【図4】本発明によって得られた柱状晶動翼と従来の柱状晶動翼の高温強度を示す比較図である。

50 【図5】一方向凝固法で製造した柱状晶動翼に見られた粒界割れの状況を示すスケッチ図である。

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【図6】合金の初期溶融を生じること無く、析出 γ' 相を γ 相中に固溶できるC量と $(B+Zr)$ 量の関係、及び粒界割れの関係を示す特性図である。

【図7】本実施例に係るガスタービンの全体構成図である。

【図8】本実施例に係る複合発電プラントの全体システム図である。

【符号の説明】

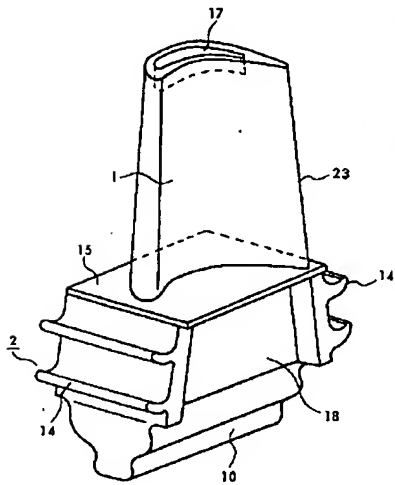
* 翼。

30

* 1…翼部、2…付根部、3…溶解炉、4…鋳造加熱炉、5…溶湯、6…鋳物、7…中子、8…セラミック鋳型、9…セレクト、10…スタータ、11…水冷銅チルプレート、12…真空ポンプ、13…炉殻、14…空冷フィン、15…プラットフォーム、16…ダブティル、18…シャンク、33…動翼、34…タービンディスク、36…コンプレッサディスク、38…スパーサ、40…静翼。

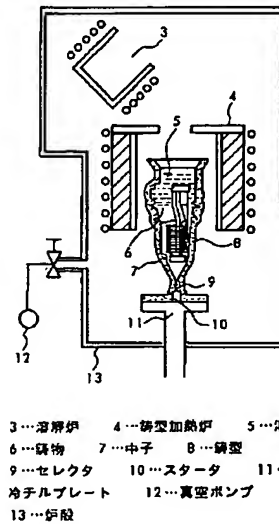
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図 1



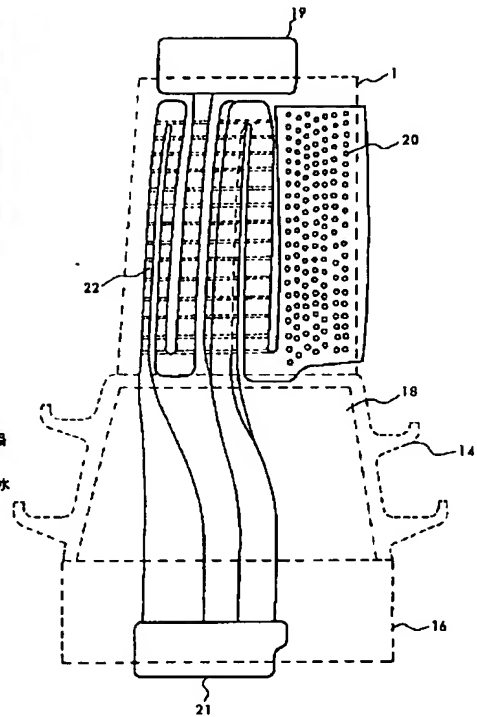
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図 2



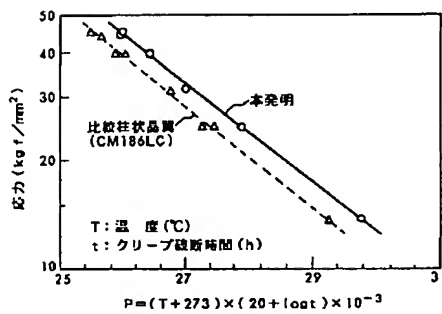
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図 3



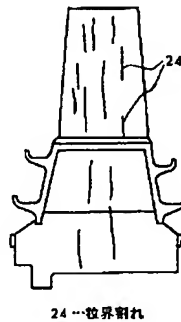
【図4】

図 4



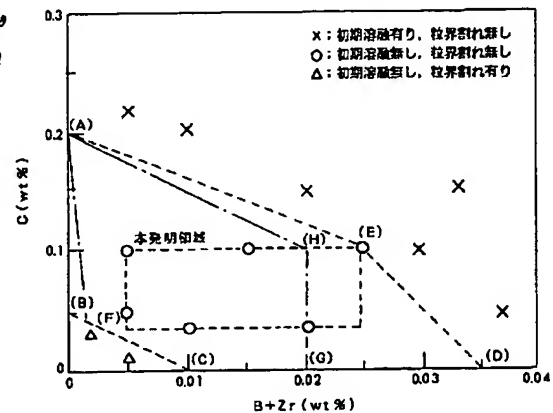
【図5】

図 5

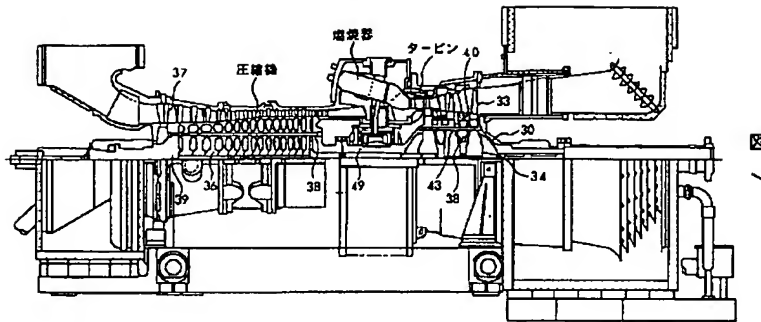


【図6】

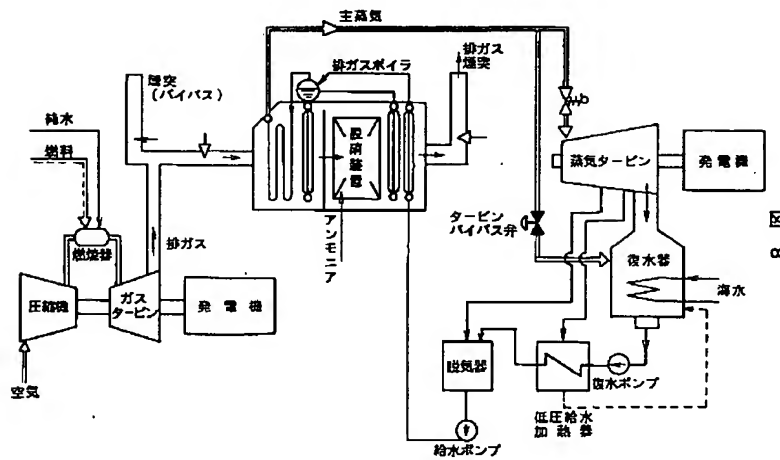
図 6



【図7】



【図 8】



フロントページの続き

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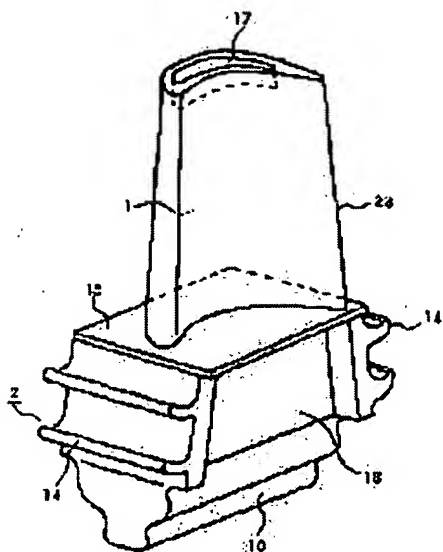
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(54) MOVING BLADE FOR GAS TURBINE, MANUFACTURE THEREOF, AND
GAS TURBINE USING SAME



(57)Abstract:

PURPOSE: To achieve excellent creep strength and eliminate an intercrystalline crack by constituting a moving blade of an integral casting where a part of a blade unit, a platform and a shank unit is made of monocrystal and a part except for the part made of monocrystal is made of columnar crystal coagulated in one direction.

CONSTITUTION: A gas turbine moving blade comprises a blade unit 1, a platform 15 having a flat portion continuous to the blade unit 1, a shank unit 18 continuous to the blade 1 and the platform 15, and fins 14 formed on both sides of the shank unit 18, a dovetail continuous to the shank unit 18. The blade unit 1 is made of monocrystal, and the whole except for the blade unit 1 is an integral casting of columnar crystal coagulated in one direction. The casting is composed of 0-0.20wt.% of C, 2-16wt.% of Cr, 4-7wt.% of Al, 2-15wt.% of W, 0.5-5wt.% of Ti,

0-3wt.% of Nb, 0-6wt.% of Mo, 0-12wt.% of Ta, 0-10.5wt.% of Co, 0-2wt.% of Hf, 0-4wt.% of Re, 0-0.035wt.% of B, 0-0.035wt.% of Zr and the rest of 58wt.% or more of Ni.

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Notes:

1. Untranslatable words are replaced with asterisks (****).
2. Texts in the figures are not translated and shown as it is.

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FULL CONTENTS

[Claim(s)]

[Claim 1] a wings part and this **** -- ** and others -- the platform which has a flat part, and this platform -- ** and others -- [part / shank] the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- in the bucket for gas turbines which has a dove tail The bucket for gas turbines characterized by consisting of a casting of one which said ****, said platform, and one copy of said shank circles are single crystals, and is pillar-shaped ** in which the portion except the portion which consists of this single crystal carried out one-way solidification.

[Claim 2] a wings part and this **** -- ** and others -- the platform which has a flat part, and this platform -- ** and others -- [part / shank] the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- in the bucket for gas turbines which has a dove tail The bucket for gas turbines characterized by consisting of a casting of one which one pair of said ****, said platform, and said shank parts is a single crystal, and is pillar-shaped ** in which all other than the portion which consists of said single crystal carried out one-way solidification.

[Claim 3] applying at the tip of **** from said dove-tail part in Claim 1 or 2 -- an inside - one -- ** and others -- the bucket for gas turbines in which the refrigerant passage is established.

[Claim 4] a wings part and this **** -- ** and others -- [it has a root part and] in the bucket for gas turbines which consists of a casting of one The bucket for gas turbines which one pair of said ****, said platform, and said shank parts is a single crystal, and it is pillar-shaped ** which carried out one-way solidification except the portion which consists of said single crystal, and is characterized by having solidified toward said root part from said **** tip.

[Claim 5] a wings part and this **** -- ** and others -- the bucket for gas turbines characterized by the difference of the crystal direction of said **** and a root part being 2 to 8 times in the bucket for gas turbines which has a root part and consists of a casting of one.

[Claim 6] a wings part and this **** -- ** and others -- the platform which has a flat part, and this platform -- ** and others -- [part / shank] the fin which consists of a projection prepared in the both sides of this shank part, and said SHIYANKU part -- ** and others -- the bucket for gas turbines which this bucket consists of a casting of one and is characterized by the difference of the crystal direction of each part being 2 to 8 times in the bucket for gas turbines which has a dove tail.

[Claim 7] In either of Claim 1 -6, said casting is weight. W 2 to 15% and 0.5 to 5% of Ti of C0-0.20%, 2 to 16% of Cr, and aluminum [4 to 7% of], 0 to 3% of Nb, 0 to 6% of Mo, 0 to 12% of Ta, 0 to 10.5% of Co, 0 to 2% of Hf, and 0 to 4% of ReB 0 to 0.035% and 0 to 0.035% of Zr, And the bucket for gas turbines which the remainder becomes from 58% or more of nickel.

[Claim 8] By weight, W 2 to 15% and 0.5 to 5% of Ti of C0-0.20%, 2 to 16% of Cr, and aluminum [4 to 7% of], 0 to 3% of Nb, 0 to 6% of Mo, 0 to 12% of Ta, 0 to 10.5% of Co, 0 to 2% of Hf, Re 0-4, B0-0.035%, 0 to 0.035% of Zr, The remainder consists of 58% or more of nickel, and both said amount of C, B, and both [one side or] of Zr(s) And A (C0.20% and B+Zr0%), The bucket for gas turbines which is within the limits of B (C0.05% and B+Zr0%), C (C0% and B+Zr0.01%), D (C0% and B+Zr0.035%), and E (C0.1% and B+Zr0.025%), and is characterized by the difference of a crystal direction being 2 to 6 times.

[Claim 9] A wings part has pillar-shaped ** and a single crystal and a dove tail [weight] W 8 to 11%, 1.0 to 3.5% of Re, 0.3 to 1.0% of Mo, 3 to 4% of Ta and 5 to 6% of aluminum of C0.03-0.1%, 5.5 to 9.0% of Cr, and Co [8.5 to 10.5% of], 0.5 to 1.5% of Ti, 0.5 to 1.0% of Hf, B And the bucket for gas turbines to which 0.005 to 0.025% and the remainder are [one sort or both of Zr] nickel and inescapable impurities, and the difference of a crystal direction is characterized by being 15 or less degrees in 8 or less times and pillar-shaped ***** in a single crystal portion.

[Claim 10] a wings part and this **** -- ** and others -- the platform which has a flat part, and this platform -- ** and others -- [part / shank] the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- in the bucket for gas turbines which has a dove tail said **** being a single crystal, being the casting of one which consists of pillar-shaped ** in which said dove tail carried out one-way solidification, and applying at the tip of **** from said dove-tail part -- an inside -- one -- ** and others -- [a refrigerant passage is prepared, and / a casting / said casting is weight and] W 2 to 15% and 0.5 to 5% of Ti of C0-0.20%, 2 to 16% of Cr, and aluminum [4 to 7% of], 0 to 3% of Nb, 0 to 6% of Mo, 0 to 12% of Ta, 0 to 10.5% of Co, 0 to 2% of Hf, Re 0-4, B0-0.035%, and 0 to 0.035% of Zr, The remainder consists of 58% or more of nickel, and both said amount of C, B, and both [one side or] of Zr(s) And A (C0.20% and B+Zr0%), Are within the limits of B (C0.05% and B+Zr0%), C (C0% and B+Zr0.01%), D (C0% and B+Zr0.035%), and E (C0.1% and B+Zr0.025%), and it has the organization where gamma' ** deposited in the gamma-phase matrix. The bucket for gas turbines characterized by the difference of said gamma-phase crystal direction being 2 to 6 times.

[Claim 11] In the gas turbine which makes it collide with the bucket in which the fuel gas compressed by the compressor was implanted by the disk through ****, and rotates this bucket having three or more steps of said bucket -- the first rank of this bucket -- a wings part and this **** -- ** and others -- [platform / which has a flat part] this platform -- ** and others -- a shank, the fin which consists of a projection prepared in the both sides of this shank, and said shank -- ** and others -- the gas turbine which it has a dove tail, and said **** is a single crystal, and is characterized by consisting of a casting of one which consists of pillar-shaped ** in which said dove tail carried out one-way solidification.

[Claim 12] In the gas turbine which makes it collide with the bucket in which the combustion gas compressed by the compressor was implanted by the disk through ****,

and rotates this bucket Said temperature of combustion gas is 1,500 degrees C. It is above, and has three or more steps of said bucket, and said temperature of combustion gas in the first rank entrance of this bucket is 1,300 degrees C. It is above and the first rank of said bucket is 200mm or more in full length. The gas turbine which consists of a casting of one which the wings part is a single crystal and is pillar-shaped ** in which said root part carried out one-way solidification, and is characterized by power generation capacity being 50,000kW or more.

[Claim 13] In the gas turbine which makes it collide with the bucket in which the combustion gas compressed by the compressor was implanted by the disk through ****, and rotates this bucket Said temperature of combustion gas is 1,500 degrees C. It is above, and has three or more steps of said bucket, and said temperature of combustion gas in the first rank entrance of this bucket is 1,300 degrees C. It is above and the first rank of said bucket is 200mm or more in full length. the first rank of said bucket -- a wings part and this **** -- ** and others -- [platform / which has a flat part] this platform -- ** and others -- a shank part, the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- in the bucket for gas turbines which has a dove tail Said **** is a single crystal, it consists of a casting of one which consists of pillar-shaped ** in which said dove tail carried out one-way solidification, and said casting is weight. C0.03-0.1%, 5.5 to 9.0% of Cr, and Co8.5 - [both W 8 to 11%, 1.0 to 3.5% of Re, 0.3 to 1.0% of Mo, 3 to 4% of Ta and 5 to 6% of aluminum of 10.5%, 0.5 to 1.0% of Ti, 0.5 to 1.0% of Hf, and B and Zr] 0.005 to 0.025% [both / one sort or] And the remainder consists of nickel and inescapable impurities and it has the organization where gamma' ** deposited in the gamma-phase matrix. The gas turbine characterized by for gamma-phase [of said single crystal] and the difference of the gamma-phase crystal direction of pillar-shaped ** being 8 or less times, and power generation capacity being 50,000kW or more.

[Claim 14] The gas turbine driven with the combustion gas which flows at high speed, and the exhaust heat recovery boiler which obtains steam with the flue gas of this gas turbine, In the combined cycle power generation plant system equipped with the steam turbine driven with said steam, and the dynamo driven with said gas turbine and a steam turbine Said gas turbine has three or more steps of buckets, and said bucket first rank inlet temperature of said combustion gas is 1,300 degrees C. It is above. The flue gas temperature of a turbine exit is 560 degrees C or more, and steam of 530 degrees C or more is obtained with said exhaust heat recovery boiler. Said steam turbine is a height pressure integral type, and said steamy temperature to the first rank of this steam turbine bucket is 530 degrees C or more. The power generation capacity of said gas turbine is [50,000kW or more and the power generation capacity of a steam turbine] 30,000kW or more, comprehensive thermal efficiency is 45% or more, the first rank of said bucket is 200mm or more in full length, and the first rank of said bucket A wings part, this wings part -- ** and others -- the platform which has a flat part, and this platform -- ** and others -- a shank part, the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- [it has a dove tail, and / **** / said **** is a single crystal and] Said dove tail consists of a casting of one which is pillar-shaped ** which carried out one-way solidification, and said casting is weight. C0.03-0.1%, 5.5 to 9.0% of Cr, and Co8.5 - [both W 8 to 11%, 1.0 to 3.5% of Re, 0.3 to 1.0% of Mo, 3 to 4% of Ta and 5 to 6% of aluminum of 10.5%, 0.5 to 1.0% of Ti, 0.5 to 1.0%

of Hf, and B and Zr] 0.005 to 0.025% [both / one sort or] And the combined cycle power generation plant system which the remainder consists of nickel and inescapable impurities, has the organization where gamma' ** deposited in the gamma-phase matrix, and is characterized by gamma-phase [of said single crystal] and the difference of a gamma-phase crystal direction of pillar-shaped ** being 8 or less times.

[Claim 15] a wings part and this **** -- ** and others -- [it has a root part and] in the manufacturing process of the bucket for gas turbines which consists of a casting of one The process which sets the mold which forms this bucket on a water-cooled CHIRUPU rate, and the process which sets said mold in a heating furnace and heats a mold to predetermined temperature, The process which casts **** in the mold by which account heating of vacuum-melting back to front was carried out in casting materials, [this ****] [the mold which it has] [the process which draws out at a speed earlier than the drawer speed of the mold of this ****, carries out one-way solidification of said root part, and is made into pillar-shaped ** after drawing out relatively from said heating furnace, applying to said root part side termination from said **** tip, making it solidify one by one and using said **** as a single crystal] The manufacturing process of the bucket for gas turbines characterized by having.

[Claim 16] Goods which consist of a one-way solidification casting of one of a single crystal and pillar-shaped **, and are characterized by the difference of the crystal direction in the right-angled direction being 8 or less times to said solidification direction of said single crystal and pillar-shaped **.

[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to the bucket which started the new bucket for gas turbines, especially was excellent in creep strength, its manufacturing process, and the gas turbine using it.

[0002]

[Description of the Prior Art] Although the bucket material of the gas turbine for power generation has mainly been used [the super alloy of nickel machine] from the former, in order that improvement in thermal efficiency of a gas turbine may be aimed at, temperature of combustion gas has risen every year. And in order to raise the heat-resistant intensity of a bucket in connection with it, while usually changing from homaxial **** by casting to pillar-shaped **** by one-way solidification systematically, the complicated cooling hole was prepared in the inside of wings, and cooling from an inside has been aimed at.

[0003] The great portion of pillar-shaped ***** is manufactured by the one-way solidifying method shown in the JP,51-4186,B number etc. This method is a method which pulls out a mold below out of the heated furnace, and the upper part is made to solidify gradually from a lower end. By this method, it was extended for a long time to the longitudinal direction on which centrifugal stress acts, and pillar-shaped ***** which has the crystal direction of <100> directions was manufactured, and the creep strength characteristic and a thermal fatigue strength property have been improved.

[0004] Moreover, the manufacturing process of the shuttlecock for combustion turbines which used the wings part as the single crystal as a bucket which excelled pillar-shaped

***** in the high temperature characteristic at JP,S60-261659,A and JP,61-71168,A, and used the root part as micro crystallite is indicated.

[0005]

[Problem to be solved by the invention] Furthermore, in order to attain efficient-ization, it is the most effective method to raise temperature of combustion gas, and it has been necessary to raise the high temperature intensity of material, while strengthening internal intercooling further for that purpose.

[0006] the internal intercooling hole of the bucket for gas turbines -- ceramics -- although formed using a core, in order to strengthen cooling further, while increasing the number of the paths for cooling, the thinning of the wings themselves has been attained. although pillar-shaped ***** is manufactured by the one-way solidifying method, melting metal is ***** about a core -- it solidifies in the state and is cooled to room temperature after that. And heat contraction is produced at the time of cooling. when the thermal expansion coefficient of a core and casting metal is compared, in order that a core may show a value smaller about single figure than metal, metal is ***** inside about the hardly contracted core -- as -- contracting -- ***** -- cooling -- big in process -- it will pull and stress will occur. For this reason, a casting article becomes easy to generate a vertical crack along the crystal grain community where intensity is weak. And especially a vertical crack is remarkable in the wings part which is a thin-walled part. For the reason, the conventional pillar-shaped ***** was not fully able to be cooled by the ability not performing the thinning of a wings part. Moreover, the **** crack occurred at the time of casting, and the yield was also bad.

[0007] The length of a wing of about 10cm and weight of the bucket used for the jet engine for airplanes is hundreds of g at the maximum, and single-crystal-izing is easy. [however, the bucket used for the gas turbine for power generation] Single crystal-ization has become [the different crystal, the FUREKKURU defect, etc.] that the form of wings is not only complicated, but the length of a wing is easy to generate in the way in JP,S51-4186,B since 15-40cm and weight also become very large with several to about 10kg very difficult.

[0008] The manufacturing process which uses a single crystal for a wings part, uses magnetic churning for the remaining portion, and is used as a minute crystal grain is stated to JP,S60-261659,A and JP,61-71168,A. However, when the conventional single crystal alloy was cast in this method, there was a problem to which the intensity of a minute crystal grain portion becomes weak. Moreover, in order to maintain the intensity of a minute crystal grain portion, when it cast using the alloy having contained a lot of **** strengthening elements, since the melting point of eutectic structure and eutectic crystal gamma' ** formed at the time of solidification fell, ***** was not made enough and was not able to aim at improvement in intensity of material as a result.

[0009] As stated above, in the bucket by the conventional technology, if thinning is carried out in order to aim at improvement in cooling efficiency, in order to become easy to generate a **** crack and to prevent a **** crack, when a **** strengthening element is added, there is a fault that the improvement in intensity cannot be aimed at, and improvement in efficiency of a gas turbine was not able to be aimed at.

[0010] Moreover, since the single crystal bucket excellent in high temperature intensity tends to have generated a different crystal, since the thing with it was not able to be manufactured, it could not be applied as a bucket of the gas turbine for power generation,

and was not able to aim at improvement in efficiency of a gas turbine. [a very bad and yield and] [big]

[0011] The purpose of this invention does not have the **** crack at the time of casting, and there is in offering pillar-shaped ***** for gas turbines which was moreover excellent in creep strength, and the gas turbine using the manufacturing process and it.

[0012]

[Means for solving problem] The platform which is an overhang part for this invention standing in a row in the wings part exposed to high temperature high pressure gas, and this ****, and intercepting high temperature high pressure gas, The shank part which has the distance for standing in a row in this platform, and acquiring temperature gradient sufficient between this **** and a disk, The seal fin which is the projection for intercepting the high temperature high pressure gas formed in this shank part, It has the dove tail which is an embedding part to the disk which stands in a row in this shank part. The external surface is a single crystal at least, and said **** is a bucket for gas turbines which it has the single crystal formed succeeding one copy of a wings part to a shank part including the wings circles part, and the remainder becomes from the casting of one which consists of pillar-shaped ** which was continuously formed from this single crystal, and which carried out one-way solidification.

[0013] That is, as for the bucket for gas turbines concerning this invention, although a wings part is a single crystal and the remainder consists of one-way solidification pillar-shaped **, the single crystal from a wings part is succeedingly formed in the remaining platforms and shank circles.

[0014] As for especially the bucket for gas turbines concerning this invention, it is desirable to make especially into less than 8 times the crystal direction difference of pillar-shaped ** which the direction of the longitudinal direction of pillar-shaped ** is less than 15 degrees from <100> directions considering a multi-crystal part as pillar-shaped *****, and adjoins 15 degrees.

[0015] Moreover, if the crystal direction difference in the single crystal of a wings part is less than 8 times, **** in particular is not seen but is permissible.

[0016] The direction difference between the crystal grains with which a wings outside side adjoins especially is less than 8 times, and it is desirable that the direction difference between the crystal grains with which a part of portion containing these wings circles parts other than this wings outside side adjoins makes the direction difference between the crystal grains with which the remainder adjoins less than 15 degrees less than 8 times.

[0017] Furthermore, as for the difference of the greatest crystal direction of the crystal grain of the portions of a wings part and others, it is desirable that it is less than 8 to 15 degrees.

[0018] Moreover, in order to obtain the above-mentioned gas turbine bucket, it is effective to prepare a solidification promotion passage between the seal fins which are at least one place and projection of a single crystal.

[0019] It applies to a wings part from a dove tail, and the refrigerant passage for cooling a bucket inside may be established in the gas turbine bucket of this invention.

[0020] The gas turbine bucket of this invention may be coated with the alloy layer which makes the main ingredients Co or nickel which contains Cr, aluminum, and Y on the **** surface.

[0021] Furthermore, the gas turbine bucket of this invention may have thermal insulation

coating which becomes said **** and the outermost surface of the circumference of it from a ceramic layer.

[0022] The bucket for gas turbines concerning this invention is 0.03% at weight. The above C, 0.005% or more of B, and 0.005% A kind of Zr of a more than or two sorts or more of elements are included. And deposit gamma' ** is cast in nickel basis super alloy which can dissolve in gamma-phase, without producing initial melting by local melting in **** of an alloy.

[0023] especially -- one sort of C0.05-0.1%, and B and Zr, or two sorts -- 0.005 to 0.025% -- desirable -- B0.002-0.02% and Zr0.02% It is suitable for carrying out the following to prevent a crack.

[0024] The bucket for gas turbines concerning this invention is weight %, and is cast in nickel basis super alloy of the following suitable composition.

[0025] A casting is weight % and W 2 to 15% and 0.5 to 5% of Ti of C0-0.20%, 2 to 16% of Cr, and aluminum [4 to 7% of, 0 to 3% of Nb, 0 to 6% of Mo, 0 to 12% of Ta, 0 to 10.5% of Co, 0 to 2% of Hf, and 0 to 4% of ReB 0 to 0.035% and 0 to 0.035% of Zr, And the remainder consists of 58% or more of nickel.

[0026] this invention -- a wings part and this **** -- ** and others -- [platform / which has a flat part] this platform -- ** and others -- a shank part, the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- in the bucket for gas turbines which has a dove tail Said **** is a single crystal and the portion except said **** and said fin is characterized by consisting of a casting of one which is pillar-shaped ** which carried out one-way solidification.

[0027] this invention -- a wings part and this **** -- ** and others -- [platform / which has a flat part] this platform -- ** and others -- a shank part, the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- in the gas turbine bucket which has a dove tail Said **** is a single crystal and all other than said **** are characterized by consisting of a casting of one which is pillar-shaped ** which carried out one-way solidification.

[0028] the bucket in this invention -- an inside -- one -- ** and others -- it has a refrigerant passage.

[0029] This invention is weight and W 2 to 15% and 0.5 to 5% of Ti of C0-0.20%, 2 to 16% of Cr, and aluminum [4 to 7% of], 0 to 3% of Nb, 0 to 6% of Mo, 0 to 12% of Ta, 0 to 10.5% of Co, 0 to 2% of Hf, and 0 to 4% of ReB 0 to 0.035% and 0 to 0.035% of Zr, The remainder consists of 58% or more of nickel, and both said amount of C, B, and both [one side or] of Zr(s) And A (C0.20% and B+Zr0%), It is within the limits of B (C0.05% and B+Zr0%), C (C0% and B+Zr0.01%), D (C0% and B+Zr0.035%), and E (C0.1% and B+Zr0.025%), and is in the bucket for gas turbines characterized by the difference of a crystal direction being 2 to 8 times.

[0030] This invention is weight: C0.03-0.1%, 5.5 to 7.0% of Cr, and Co8.5 - [both W 8 to 9%, 2.5 to 3.5% of Re, 0.3 to 1.0% of Mo, 3 to 4% of Ta and 5 to 6% of aluminum of 9.5%, 0.5 to 1.0% of Ti, 0.5 to 1.0% of Hf, and B and Zr] 0.005 to 0.025% [both / one sort or] And the remainders are nickel and inescapable impurities and it is in the bucket for gas turbines characterized by the difference of a crystal direction being 8 or less times.

[0031] Although the bucket of this invention is used for three steps or four steps of which stages of a gas turbine, it is suitable for the first rank whose temperature is especially the

highest. The thing of the many crystals which made the whole pillar-shaped ** or ***** is suitable especially after two step.

[0032] The following composition is especially suitable (weight %).

[0033]

: C 0.03-0.1 Cr: 5.5-7.0 Co : 9-10.5 : 8.0-11.0 Re : W 1.0-3.5 Mo: 0.3-1.0 Ta : 3.0-4.0 aluminum: 5.0 - 6.0 Ti : 0.5-1.0 one sort or two sort [of Hf:0.5-1.0 B and Zr]: -- 0.005 to 0.025 remainder: -- [nickel, inescapable impurities, and the bucket for gas turbines concerning this invention] It is [more than dissolution temperature of gamma' ** of an after-casting alloy] suitable for a ** object to turn in the temperature range below initial melting temperature for 2 to 60 hours, and to give heat treatment at further 1000-1150 degrees C for 8 to 100 hours at 4 to 20 hours and 800-920 degrees C.

[0034] [moreover, the manufacturing process of the bucket for gas turbines concerning this invention] ceramics -- [process / which sets the mold which has a core on a water-cooled CHIRUPU rate] The process which casts ***** in the mold heated after dissolving casting materials, and the process which draws out a mold relatively from a hot heating furnace, is made to carry out one-way solidification from the ***** tip side gradually to the root part side, and uses a wings part as a single crystal, It is in the manufacturing process of the gas turbine bucket characterized by drawing out at a speed earlier than the drawer speed of the mold of this wings part, and carrying out one-way solidification of the root part.

[0035] It is desirable to make mold movement speed in single crystal manufacture into 15 or less cm/h. It is desirable to make movement speed in pillar-shaped ***** into 20 - 45 cm/h. Since it is better as especially the former can carry out single crystal manufacture and there is, but the crystal direction between pillar-shaped ** will exceed 10 degrees and will serve as ***** from a point of the yield again, if about 10 cm/h is desirable and the latter exceeds h in 50cm / Since it is good in 45cm/h or less and the early speed is better for considering it as 8 or less times, 30 - 45 cm/h is desirable.

[0036] This invention consists of a one-way solidification casting of one of a single crystal and pillar-shaped **, is in the goods characterized by the difference of the crystal direction in the right-angled direction being 8 or less times to said solidification direction of said single crystal and pillar-shaped **, and can be used in addition to the bucket for gas turbines.

[0037] this invention -- a wings part and this ***** -- ** and others -- [platform / which has a flat part] this platform -- ** and others -- a shank part, the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- in the gas turbine bucket which has a dove tail said ***** being a single crystal, and all other than said ***** being the castings of one which are pillar-shaped ** which carried out one-way solidification, and applying at the tip of ***** from said dove-tail part -- an inside -- one -- ** and others -- [a refrigerant passage is prepared, and / a casting / said casting is weight and] W 2 to 15% and 0.5 to 5% of Ti of C0-0.20%, 2 to 16% of Cr, and aluminum [4 to 7% of], 0 to 3% of Nb, 0 to 6% of Mo, 0 to 12% of Ta, 0 to 10.5% of Co, 0 to 2% of Hf, Re 0-4, B0-0.035%, and 0 to 0.035% of Zr, The remainder consists of 58% or more of nickel, and both said amount of C, B, and both [one side or] of Zr(s) And A (C0.20% and B+Zr0%), Are within the limits of B (C0.03% and B+Zr0%), C (C0% and B+Zr0.01%), D (C0% and B+Zr0.035%), and E (C0.1% and B+Zr0.025%), and it has the organization which gamma' ** distributed in the gamma-

phase matrix. It is characterized by the difference of said gamma-phase crystal direction being 2 to 6 times.

[0038] In the gas turbine which makes this invention collide with the bucket in which the combustion gas compressed by the compressor was implanted by the disk through ****, and rotates this bucket having three or more steps of said bucket -- the first rank of this bucket -- a wings part and this **** -- ** and others -- [platform / which has a flat part] this platform -- ** and others -- [fin / a shank and / which consists of a projection prepared in the both sides of this shank] said shank -- ** and others -- the gas turbine characterized by consisting of a casting of one which it has a dove tail, and said **** is a single crystal, and is pillar-shaped ** in which said **** and all other than said fin carried out one-way solidification.

[0039] In an above-mentioned gas turbine, said temperature of combustion gas of this invention is 1,500 degrees C. It is above. It has three or more steps of said bucket, and said temperature of combustion gas in the first rank entrance of this bucket is 1,300 degrees C. It is above and the first rank of said bucket is 200mm or more in full length. The wings part is a single crystal, and the root part except this **** consists of a casting of one which is pillar-shaped ** which carried out one-way solidification, and it is characterized by power generation capacity being 50,000kW or more.

[0040] In the gas turbine which makes this invention collide with the bucket in which the combustion gas compressed by the compressor was implanted by the disk through ****, and rotates this bucket Said temperature of combustion gas is 1,500 degrees C. It is above, and has three or more steps of said bucket, and said temperature of combustion gas in the first rank entrance of this bucket is 1,300 degrees C. It is above and the first rank of said bucket is 200mm or more in full length. the first rank of said bucket -- a wings part and this **** -- ** and others -- [platform / which has a flat part] this platform -- ** and others -- a shank part, the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- in the bucket for gas turbines which has a dove tail It consists of a casting of one which said **** is a single crystal and is pillar-shaped ** which carried out one-way solidification except for said fin, and said casting is weight. C0.03-0.1%, 5.5 to 9.0% of Cr, and Co8.5 - [both W 8 to 11%, 1.0 to 3.5% of Re, 0.3 to 1.0% of Mo, 3 to 4% of Ta and 5 to 6% of aluminum of 10.5%, 0.5 to 1.0% of Ti, 0.5 to 1.0% of Hf, and B and Zr] 0.005 to 0.025% [both / one sort or] And the remainder consists of nickel and inescapable impurities and it has the organization where gamma' ** deposited in the gamma-phase matrix. Gamma-phase [of said single crystal] and the difference of the gamma-phase crystal direction of pillar-shaped ** are 8 or less times, and it is characterized by power generation capacity being 50,000kW or more.

[0041] The gas turbine which drives this invention with the combustion gas which flows at high speed, The exhaust heat recovery boiler which obtains steam with the flue gas of this gas turbine, In the combined cycle power generation plant system equipped with the steam turbine driven with said steam, and the dynamo driven with said gas turbine and a steam turbine Said gas turbine has three or more steps of buckets, and said bucket first rank inlet temperature of said combustion gas is 1,300 degrees C. It is above. The flue gas temperature of a turbine exit is 560 degrees C or more, and steam of 530 degrees C or more is obtained with said exhaust heat recovery boiler. Said steam turbine is a height pressure integral type, and said steamy temperature to the first rank of this steam turbine

bucket is 530 degrees C or more, the power generation capacity of said gas turbine is [50,000kW or more and the power generation capacity of a steam turbine] 30,000kW or more, and it is characterized by comprehensive thermal efficiency being 45% or more.

[0042] The gas turbine driven with the combustion gas which flows at high speed, and the exhaust heat recovery boiler which obtains steam with the flue gas of this gas turbine, In the combined cycle power generation plant system equipped with the steam turbine driven with said steam, and the dynamo driven with said gas turbine and a steam turbine A bucket has three or more steps and said bucket first rank inlet temperature of said combustion gas of said gas turbine is 1,300 degrees C. It is above. The flue gas temperature of a turbine exit is 560 degrees C or more, and steam of 530 degrees C or more is obtained with said exhaust heat recovery boiler. Said steam turbine is a height pressure integral type, and said steamy temperature to the first rank of this steam turbine bucket is 530 degrees C or more. The power generation capacity of said gas turbine is [50,000kW or more and the power generation capacity of a steam turbine] 30,000kW or more, comprehensive thermal efficiency is 45% or more, the first rank of said bucket is 200mm or more in full length, and the first rank of said bucket A wings part, this wings part -- ** and others -- the platform which has a flat part, and this platform -- ** and others -- a shank part, the fin which consists of a projection prepared in the both sides of this shank part, and said shank part -- ** and others -- [it has a dove tail, and / **** / said **** is a single crystal and] It consists of a casting of one which is pillar-shaped ** which carried out one-way solidification except for said fin, and said casting is weight. W 8 to 11%, 1.0 to 3.5% of Re, 0.3 to 1.0% of Mo, 3 to 4% of Ta and 5 to 6% of aluminum of C0.03-0.1%, 5.5 to 9.0% of Cr, and Co [8.5 to 10.5% of], 0.5 to 1.0% of Ti, 0.5 to 1.0% of Hf, B And 0.005 to 0.025% and the remainder consist of nickel and inescapable impurities, one sort or both of Zr have the organization where gamma' ** deposited in the gamma-phase matrix, and it is characterized by gamma-phase [of said single crystal] and the difference of a gamma-phase crystal direction of pillar-shaped ** being 8 or less times.

[0043] The bucket for gas turbines concerning this invention contains a kind of 0.20% or less of C, and 0.002 to 0.02% of B and 0.002% or more of Zr, and 0.5% or more of Hf, or two sorts or more of elements by weight %. And it is cast in nickel basis super alloy which can dissolve about 60% or more of deposit gamma' ** in gamma-phase at the rate of volume, without producing initial melting by local melting about 5% or more at the rate of volume.

[0044] Making 0.002 to 0.20% and Hf into 0.5 to 1.1% for a kind of B and Zr or two sorts C0.03-0.1% especially prevents a crack. And without producing initial melting about 5% or more at the rate of volume, are suitable in order to make about 60% or more of deposit gamma' ** dissolve in gamma-phase at the rate of volume. It is desirable to make said amount of C and the amount of B+Zr into the range of A (C0.20% and B+Zr0%), F (C0.04% and B+Zr0.002%), C (C0% and B+Zr0.01%), G (C0% and B+Zr0.02%), and H (C0.10% and B+Zr0.20%).

[0045] In order to satisfy all, such as a **** crack at the time of casting, creep strength, corrosion resistance, oxidation resistance, and heat-resistant fatigue characteristics Especially W 7 to 10% and 0.5 to 1% of Ti of 6.0 to 9.0% of Cr, and aluminum [5 to 6% of], 0.3 to 0.7% of Mo, 3.0 to 7.0% of Ta, 1 to 3.4% of Re, and 8 to 10.5% of CoC 0.03 to 0.1%B 0.002 to 0.02%, 0.5 to 1.1% of Hf and Zr0.02% Following, And the

composition whose remainders are nickel and inescapable impurities is suitable.

[0046] Moreover, although the bucket of this invention can use a turbine for any turbine of three steps or the gas turbine which it has four steps, metal temperature is especially the most suitable for it to the first rank turbine which becomes high. What made the whole pillar-shaped ** or ***** is used after the second step in many cases.

[0047] It is [more than dissolution temperature of deposit gamma' ** of an after-casting alloy] suitable for the bucket for gas turbines of this invention for a ** object to turn in the range below initial melting temperature for 2 to 60 hours, and to give heat treatment by further 1000 to 1150% for 8 to 100 hours at 4 to 20 hours and 800-920 degrees C.

[0048] Moreover, the process which sets a mold for the bucket for gas turbines of this invention to form this bucket on a water-cooled CHIRUPU rate, The process which heats said mold to a predetermined temperature within a vacuum heating furnace, and the process which casts **** to the mold with which casting materials were dissolved within the same vacuum chamber as a mold, and the above was heated, After drawing out the mold containing this **** from said heating furnace, making one-way solidification carry out in the direction of a dove tail one by one from said **** and using said **** as a single crystal, Said platform or subsequent ones is drawn out at a speed earlier than the drawer speed of said ****, and it is manufactured by the single crystal which carried out one-way solidification of a part of portions other than said **** continuously from this ****, and the process which uses the remainder as the casting of one which is pillar-shaped ** which carried out one-way solidification continuously from this single crystal.

[0049] As for the above-mentioned mold drawer speed, it is desirable to consider it as 15 or less cm/h in single crystal manufacture, and it is desirable to consider it as 20 - 45 cm/h in pillar-shaped *****. As these can be manufactured, respectively, they are better, but about the point of the yield to single crystal manufacture, about 10 cm/h is desirable. Since the difference of the crystal direction between pillar-shaped ** will exceed 20 degrees and will serve as ***** further about pillar-shaped **, if 50 cm/h is exceeded a too slow [drawer speed] thing in order for the crystal direction difference between pillar-shaped ** which 45 or less cm/h is good for, and adjoins to obtain good pillar-shaped ** of 15 or less degrees -- it is 30 - 45 cm/h suitably preferably.

[0050]

[Function] The bucket for gas turbines concerning this invention uses a wings part as a single crystal, and makes the crystal direction difference in a single crystal less than 8 times. and **** whose crystal direction difference of pillar-shaped ***** which makes it one-way solidification pillar-shaped ** except ****, and adjoins is made -- even if it lessens the amount of addition of a crystal grain community strengthening element by making it small and making the difference into less than 8 times especially more preferably less than 15 degrees It can be considered as pillar-shaped **** which the **** crack at the time of casting does not generate, and intensity equivalent to a single crystal can be maintained. Moreover, since the amount of addition of a crystal grain community strengthening element was written few, the melting point of eutectic structure formed at the time of casting went up and solution-heat-treatment temperature was raised, the heat treatment which makes deposit gamma' ** dissolve in gamma-phase [of ****] was attained. Therefore, it can be considered as pillar-shaped **** which has high creep strength. On the contrary, if the difference of a crystal direction exceeds 10 degrees, it will fall rapidly with about 10 to 20% of the intensity of a single crystal.

[0051] In order to raise the high temperature intensity of material, the solution heat treatment after casting is effective. By making gamma' ** which deposited after solidification dissolve completely in ****, the solution heat treatment can optimize the size and form of deposit gamma' ** by subsequent prescription heat treatment, and can raise high temperature intensity.

[0052] However, in order for the alloy used for the conventional pillar-shaped ***** to prevent the vertical crack along the crystal grain community at the time of casting, it is necessary to make many crystal grain community strengthening elements, such as B, C, Zr, and Hf, contain. While a crystal grain community strengthening element raises the intensity of a crystal grain community, the segregation of the part is carried out between DENDRO light arms, and it drops the melting point of a segregation part remarkably. In the case of nickel basis super alloy, said segregation part forms eutectic structure and produces eutectic crystal gamma' ** big and rough at the time of solidification. It is formed at this time, eutectic structure and eutectic crystal gamma' ** has the lowest melting point in an alloy, and if temperature is raised in order to perform solution heat treatment, eutectic structure will produce initial melting. Therefore, the alloy used for the conventional pillar-shaped ***** could not make solution-heat-treatment temperature high, and since ***** was inadequate, it was not able to aim at improvement in intensity of material as a result.

[0053] In addition, a crystal grain community strengthening element is dealt with as an impurities element, since content is lessened as much as possible, the melting point of eutectic crystal gamma' ** goes up, and the alloy for single crystals which does not contain a crystal grain community strengthening element makes perfect solution heat treatment possible. Therefore, from the conventional material, a single crystal alloy shows the outstanding high temperature characteristic high 40-50 degrees C, and is used as a bucket of the jet engine for airplanes. However, since the single crystal alloy lessens the crystal grain community strengthening element as much as possible, its crystal grain community is very as weak as formation ****, and if there is a different crystal from which a crystal direction differs, a crack will enter easily on the crystal grain community. If there is a crystal grain community, it will usually become the weakness which is the grade into which a crack goes only by cooling after casting. Therefore, it is necessary to use as a perfect single crystal without a different crystal the bucket cast using the single crystal alloy.

[0054] Moreover, it is the alloy containing the aforementioned **** strengthening element, and, naturally it is also possible to use the whole bucket as a single crystal. Although the creep strength in high temperature is inferior compared with the single crystal bucket cast in the alloy only for a single crystal with which this bucket does not contain a crystal grain community strengthening element Except the wings outside side which becomes high temperature, since the direction difference between adjoining crystal grains is permissible to 15 degrees, the crystal direction measurement by the X-rays which were required of the conventional single crystal bucket can be simplified sharply. Furthermore, there is no effective inspection means to the crystal defect inside wings, it usually extracts, and wings are cut and inspected by the examination. However, at the bucket for the gas turbines for power generation by which wings become large-sized, by the sampling examination, reservation of reliability was difficult and it had become a big neck when applying a single crystal bucket to the gas turbine for power generation.

However, in this invention, since the direction difference between adjoining crystal grains was permissible to 15 degrees, the reliability of the bucket could be improved sharply and application to the gas turbine for power generation of a high intensity bucket was attained.

[0055] The role of each element contained in nickel basis super alloy which constitutes the bucket for gas turbines is shown below.

[0056] C -- a matrix -- or [while dissolving especially to ****, carbide is formed and high temperature **** strength is raised, but] If it adds superfluously, since it will lower the melting point of **** and high temperature intensity and toughness will be reduced, especially as an amount of addition, it is 0.05 to 0.2% 0.20% or less. The range is proper and 0.03 to 0.1% is more desirable.

[0057] While Co dissolves in a matrix and raises high temperature intensity, it contributes to corrosion-resistant improvement, but if it adds superfluously, a harmful intermetallic compound deposit will be promoted and the fall of high temperature intensity will be caused. As an amount of addition, it is 10.5%. It carries out the following and is 8 to 10.5% especially. It is proper. It is 8.5% more 4% or more as a minimum in particular. The above is desirable.

[0058] Although Cr improves corrosion resistance, if superfluous addition is carried out, it will cause big and rough-ization of harmful sigma ***** or carbide, and will reduce high temperature intensity. As an amount of addition, 2 to 16%, 5 to 14% of range is preferably proper, and the range of 5.5 - 9 % is especially desirable.

[0059] aluminum and Ti deposit, gamma' ** 3 (aluminum, Ti), i.e., nickel, which is the deposit strengthening factor of nickel machine alloy, and contribute to improvement in high temperature intensity. As an amount of addition, they are aluminum:4.0-7.0 and Ti:0.5-5.0%. The range is proper and especially its 5 to 6% of aluminum and 0.5 to 1.0% of Ti are desirable.

[0060] Although Nb, Ta, and Hf dissolve to gamma' ** which is a strengthening factor and improve high temperature intensity, if it adds superfluously, a segregation will be carried out to a crystal grain community, and intensity will be reduced on the contrary on it. As an amount of addition, less than Nb3%, less than Ta12%, and less than Hf2% are proper, and 0.5 to 1.0% of Hf is [2 to 7% of Ta] especially more desirable 3 to 4% Nb:0.2-3.0%. Although especially Hf has the effect of the vertical crack prevention at the time of solidification and the ductility in high temperature is made to improve, if 2% is exceeded, the eutectic structure at the time of solidification will be increased, and effective solution treatment will be made difficult.

[0061] Although they prevent the vertical crack at the time of solidification, strengthen **** and improve high temperature intensity, Zr and B will fall ductility and toughness, if it adds superfluously, lower the melting point of **** and reduce high temperature intensity. As an amount of addition, Zr:0-0.035% and B:0 to 0.035% are proper. Especially A (C0.20% and B+Zr0%) from a relation with the amount of C, B (C0.05% and B+Zr0%), As for 0.005 to 0.025%, one sort of B and Zr or two sorts are [within the limits of C (C0% and B+Zr0.01%), D (C0% and B+Zr0.035%), and E (C0.1% and B+Zr0.025%)] desirable. The range surrounded by A, F, C, G, H, and A is desirable more preferably.

[0062] W and Mo are dissolved and strengthened to gamma-phase [of a matrix], and its effect is large to an improvement of intensity especially for a long time. However, if it

adds superfluously, harmful *****, such as sigma **, will be promoted and intensity will be reduced on the contrary. As an amount of addition, it is W2-15% and Mo6.0%. The following is proper and 0.3 to 1.0% of Mo is especially desirable W7.0-11.0%. W8-10% is more desirable.

[0063] Although Re raises high-temperature-corrosion-proof nature, if it becomes more than a certain amount of amount of addition, an effect will be saturated and the fall of ductility and toughness will be caused on the contrary. as the amount of addition -- less than Re4% -- 2.5 to 3.5% is especially more desirable 1 to 4%.

[0064]

[Working example]

[Example 1] Drawing 1 shows the perspective view of the single crystal bucket for gas turbines concerning this invention, and drawing 2 is the schematic view of the equipment in which the manufacture method of the bucket of this invention is shown.

[0065] In drawing 2, at first, the ceramic mold 8 which makes the main ingredients the alumina set on the cold-water copper CHIRUPU rate 11 is fixed, it is set into the mold heating furnace 4, and the ceramic mold 8 is heated more than the melting point of nickel basis super alloy. Next, dissolved nickel basis super alloy is cast in the ceramic mold 8, the water-cooled copper CHIRUPU rate 11 was pulled out below after that, and one-way solidification was carried out. In one-way solidification, many crystals are generated with a starter 10 at first. Next, only one crystal is grown up by a selector 9. Furthermore, a crystal is enlarged by an enlarged member and it single-crystal-izes by solidifying a wings part at the drawer speed of 10 cm/h. After the wings part solidified and single-crystal-ized, by making it quick with drawer speed 40 cm/h of a mold on a platform 15, single crystal growth of the remaining portion was not carried out, but it was considered as pillar-shaped **. By this method, as for the wings part, the single crystal organization was obtained, and pillar-shaped ***** of pillar-shaped ***** was obtained except ****. In this case, since pillar-shaped ** grew up the single crystal of a wings part as a seed, it was able to make the difference of the direction between pillar-shaped ** about 5 times. Moreover, the ceramic mold 8 was pulled out completely, and the mold heating furnace 4 was maintained at high temperature until solidification was completed.

Moreover, all the processes of the above-mentioned dissolution and solidification were performed in the vacuum. The chemical constitution of nickel basis super alloy used for casting in the casting conditions and Table 2 of the single crystal bucket is shown in Table 1. In addition, pillar-shaped ***** cast in the above-mentioned method performs 2-60h solution treatment in a vacuum at 1260-1280 degrees C after casting. Deposit gamma' ** formed by the cooling process after solidification is changed into gamma-phase, 4-20h and 800-950 degrees C perform 8-100h prescription heat treatment at 1000-1150 degrees C after that, and it is an average of 0.3-2 micrometers in gamma-phase [of a matrix]. 0.1-0.5-micrometer gamma' ** was deposited preferably.

[0066]

[Table 1]

表 1

鑄型加熱温度	1540℃
鑄込み温度	1550℃
鑄型引出し速度	翼部: 10cm/h → プラットフォーム以降: 40cm/h
鑄型材質	アルミナ系セラミック鑄型

[0067]

[Table 2]

表 2

C	0.05~0.1	Cr	5.5~7.0
Co	9.0~9.5	W	8.0~9.0
Re	2.8~3.1	Mo	0.3~0.7
Ta	3.0~4.0	Al	5.5~6.0
Ti	0.5~0.9	Hf	0.7~1.0
B	0.005~0.01	Zr	0.005~0.01
Ni	残部	—	—

[0068] When the drawer speed of the mold inserted the heat conductive pair in the portion equivalent to the platform 15 in a mold 8, measured the temperature of the portion and became a coagulating point, it was pulled out, and it changed speed. In addition, while forming the divider plate of black lead in the lower part of the heating furnace 4, a water-cooled copper pipe is spirally wound around the lower part, and the mold was cooled.

[0069] The wings part 1 of the bucket obtained in the above way is a single crystal, and the portion 2 below a platform 15 became pillar-shaped **. With the air cooling fin 14, it had become a crystal grain with a diameter of about 10mm which is hard to be called pillar-shaped **. Although it was pillar-shaped ** on the surface of the shank 18, as for the inside, small pillar-shaped ** was gradually formed from big pillar-shaped ** the single crystal of the wings part 1 grew up to be. The width of pillar-shaped ** in the surface was 5-10mm, and average width was 5-6mm. The wings part was able to check that they were all the single crystals in the outside surface by etching. Therefore, it turns out that the difference of the crystal direction in a wings part is less than 8 times.

[0070] Drawing 3 is the top view of the core of a bucket, and shows physical relationship with a bucket. The bucket in this example is made into a cave so that an inside can be cooled. Steam cooling is also applicable although air is used as a cooling medium. A refrigerant is supplied from the portion of the core 21 of a dove tail 16, and divides and flows into the portion discharged from 17 of the tip of wings, and the portion discharged from trailing EJJI 23 of wings. 20 of a core and 22 are a hole, the wings part of two sheets is united with the projection mutually formed corresponding to this hole, and the outlet of the refrigerant of trailing EJJI 23 portion has become slit-like. 22 of the core is a hole, and **** is buried by this portion, and it is been [22 / it] united and formed in it.

[0071] The length of the wings part 1 in this example is about 100mm, and has the size whose length after a platform is 120mm.

[0072] The creep rupture intensity of the bucket obtained by drawing 4 is shown using

the Larson mirror parameter P. Comparison material is commercial CM186LC. Pillar-shaped ** of the alloy was used. By performing single crystal-ized back solution heat treatment and prescription heat treatment, the durable temperature in creep improved by about 20 degrees C for 14.0 kgf/mm stress 2 or 100,000 hours compared with what performed only prescription heat treatment by the conventional pillar-shaped *****. Commercial alloy composition is B0.016% and Zr0.016% and C0.15% in the alloy composition shown in Table 2. It has.

[0073] [Example 2] Solution heat treatment was able to be performed to the bucket of this invention because the amount of addition of C, B, Zr, and Hf was controlled and eutectic structure raised the melting point. Eutectic structure is described about the method for raising the melting point below.

[0074] The alloy containing the conventional ***** strengthening element contains many C, B, Zr(s), Hf(s), etc., and solution heat treatment of it was not completed. By weight, then, Cr:5.0-14.0% Co: 0 - 12.0%W : 5.0 to 12.0% Re: 0-3.5%Mo : 0.5 to 3.0% Ta: 3.0 to 7.0%aluminum: 4.0 to 6.0% Ti:0.5-3.0%Hf: About the alloy of nickel machine containing 0 to 2.0%, the rate of the amount of C of an alloy and quantity (Zr+B) was changed, and the melting point of eutectic structure and the relation of the dissolution temperature of deposit gamma' ** were investigated. As a result, C:0.1% or less and B+Zr:0.025% It turned out that deposit gamma' ** can be dissolved in ****, without producing initial melting of eutectic structure, when making it below. However, C:0.1% or less and B+Zr:0.025% When one-way solidification pillar-shaped **** of nickel basis super alloy made into the following composition ranges was cast, the **** crack occurred. Drawing 5 shows the sketch of a **** crack of pillar-shaped ***** manufactured by the conventional one-way solidification. That is, by the conventional one-way solidifying method, when pillar-shaped ***** was manufactured C:0.1 or less weight % using the alloy not more than B+Zr:0.025 weight %, the crack arose in **** and it was not able to be used as a product.

[0075] Then, [when the crystal direction difference of pillar-shaped **, the amount of C of an alloy, quantity (Zr+B), and the relation of a **** crack are investigated, and the crystal direction difference of pillar-shaped ** is less than 8 times, C:0.03% or more if : (Zr+B) 0.005% or more healthy pillar-shaped **** without a **** crack will be obtained by weight, but] When the crystal direction difference of pillar-shaped ** was 8 times or more, the **** crack occurred also as : (Zr+B) 0.005% or more C:0.03% or more. In addition, the amount of C is 0.03%. Below, in the crystal direction difference of pillar-shaped **, the **** crack occurred at least less than 8 times. The above result is collectively shown in drawing 6 . If a crystal direction difference is made into less than 6 times, in addition, A (C0.20% and B+Zr0%), If it is in B (C0.05% and B+Zr0%), C (C0% and B+Zr0.01%), D (C0% and B+Zr0.035%), and E (C0.1% and B+Zr0.025%), what a **** crack does not have without initial melting, either will be obtained.

[0076] In order not to generate a **** crack with the alloy not more than B+Zr:0.025 weight % C:0.1 or less weight %, it was required to make the difference of a crystal direction into less than 8 times, but the conventional one-way solidifying method is random, and was not able to control the crystal direction of the transverse direction of each pillar-shaped ** within 8 times. However, by the method of this invention, the difference of the direction of pillar-shaped ** was able to be made into less than 8 times by using a wings part as a single crystal, using this single crystal as a seed, and growing

up pillar-shaped **. That is, healthy pillar-shaped **** without a **** crack was obtained less than B+Zr:0.025 weight % C:0.1 or less weight % because a direction difference uses a wings part as a single crystal and makes it pillar-shaped ** of less than 8 times except **** like this invention. B and Zr showed the same effect by either one side or both.

[0077] The feature of the bucket by pillar-shaped ***** by the conventional method, the single crystal bucket, and this invention when manufacturing the bucket of 22cm (100mm of wings parts, 120mm of root parts) of length of a wing is compared and shown in Table 3. In addition, the commercial alloy was used for casting of pillar-shaped ***** and a single crystal bucket.

[0078]

[Table 3]

表 3

翼の種類	铸造温度 (℃)	铸造時間 (h)	粒界割れ 率 (%)	欠陥発生 率 (%)	歩留り (%)	耐用温度 (℃)
柱状晶翼	1520	1.0	75	20	15	900
単結晶翼	1600	3.0	0	95	5	940
本発明	1540	1.5	0	30	70	920

[0079] Since pillar-shaped ***** by this invention did not occur [a **** crack], while rising about 5 times with 70% from 15% of the yield of the bucket, the durable temperature in creep rose by about 20 degrees C for 14.0 kgf/mm stress 2 or 100,000 hours.

[0080] When only durable temperature is measured, it is inferior to a single crystal. However, in this invention, by having made it into pillar-shaped ***** except ****, casting time was shortened and mold cooking temperature was able to be made low. As a result, there are few reactions with a mold, and since the rate of a defect decreases and the manufacture yield of a bucket improves, this inventions are very practical pillar-shaped ***** and a manufacturing process. In addition, although productivity and the yield are inferior, even if it uses the whole wings as a single crystal using this alloy, it is obvious that there is no actual harm in any way.

[0081] [Example 3] Solution heat treatment was able to be performed to the bucket of this invention because the amount of addition of C, B, Zr, and Hf was controlled and eutectic structure raised the melting point. The method for raising the melting point of eutectic structure is described below.

[0082] The alloy containing the conventional **** strengthening element contains many C, B, Zr(s), Hf(s), etc., and solution heat treatment of it was not completed. By weight, then, Cr:2.0-16.0% Co: 4 - 10.5%W : 2.0 to 15.0% Re: 0-4.0%Mo : 0 to 6.0% Ta: 2.0 to 12.0%aluminum: 4.0 to 7.0% Ti: About the alloy of nickel machine containing 0.5 to 5.0%, Hf changed the rate of the amount of C of an alloy, and quantity (Zr+B) in 0.5 to 1.1% of range, and investigated the melting point of eutectic structure, and the relation of the dissolution temperature of deposit gamma' **. As a result, B+Zr:0.020% It turned out that deposit gamma' ** can be dissolved in ****, without producing initial melting of eutectic structure, when making it below. However, Hf: When one-way solidification pillar-shaped **** of nickel basis super alloy made into the composition range not more

than B+Zr:0.020% was cast 0.5 to 1.1%, and C:0.2% or less, as shown in drawing 5 of the above-mentioned [a **** crack], it generated. Namely, Hf: 0.5 to 1.1 weight %, and C:0.2 Below weight % and B+Zr:0.020 When pillar-shaped ***** which made the crystal direction random by the conventional one-way solidifying method using the alloy below weight % was manufactured, the crack arose in **** and it was not able to be used as a product.

[0083] Then, Hf is [the crystal direction difference of pillar-shaped **, and] 0.5%. When the amount of C of an alloy, quantity (Zr+B), and the relation of a **** crack are investigated and the crystal direction difference of pillar-shaped ** is less than 15 degrees, [weight] C:0.03% or more when : (Zr+B) 0.002% or more, healthy pillar-shaped **** without a **** crack was obtained, but when the crystal direction difference of pillar-shaped ** was 15 degrees or more, the **** crack occurred also as : (Zr+B) 0.002% or more C:0.03% or more. In addition, the amount of Zr+B is 0.002%. In the crystal direction difference of pillar-shaped **, in the following, the **** crack occurred at least less than 15 degrees.

[0084] The amount of C is 0.1%. Above, they are 1040 degrees C and 14 kgf/mm². There were some by which creep fracture time is less than 400h. Moreover, what cannot perform perfect solution treatment because initial melting happens was less than 400h. The relation between the amount of C in case Hf is [the crystal direction difference of pillar-shaped **] less than 15 degrees at 0.5 to 1.1%, and the amount of Zr+B Moreover, A (0.2%, 0%), It is obtained by within the limits surrounding each point of F (0.04%, 0.002%), C (0%, 0.01%), G ([0% of] 0.02%), and H (0.1%, 0.02%).

Hf : [in order not to generate a **** crack with the alloy not more than B+Zr:0.020 weight % 0.5 to 1.1%, and C:0.2 or less weight %, it is required to make the difference of a crystal direction into less than 15 degrees, but] The conventional one-way solidifying method is random, and was not able to control the crystal direction of the transverse direction of each pillar-shaped ** within 15 degrees. However, by the method of this invention, the difference of the direction of pillar-shaped ** was able to be made into less than 15 degrees by using a wings part as a single crystal, using this single crystal as a seed, and growing up pillar-shaped **. That is, it is Hf:0.5 -1.1 by a direction difference using a wings part as a single crystal, and making it pillar-shaped ** of less than 15 degrees except **** like this invention. Weight % and C:0.2 Below weight % and B+Zr:0.020 Healthy pillar-shaped **** in which below weight % does not have a **** crack was obtained. B and Zr showed the same effect by either one side or both.

[0085] Casting conditions and alloy composition (weight %) are shown in Table 4. The remainder is nickel.

[0086]

[Table 4]

表 4

焼成温度	焼成条件			クリープ										元素組成										
	温度	時間	冷却時間	クリープ時間	クリープ変位	クリープ速度	クリープ断面積	クリープ断面積	クリープ断面積	クリープ断面積	クリープ断面積	クリープ断面積	C	Cr	Co	W	Re	Mo	Ta	Al	Ti	Hf	B	Zr
本発明	1540℃	1.5h	0%	70%	456h	102	108	98	90	8.0	8.0	8.0	0.05	5.5	8.0	8.0	2.8	0.3	3.0	5.5	0.5	0.7	0.015	0.0025
従来品	1520℃	1.0h	75%	20%	193h	100	107	98	90	8.0	8.0	8.0	0.05	5.5	8.0	8.0	2.8	0.3	3.0	5.5	0.5	0.7	0.015	0.0025
従来品	1600℃	3.0h	0%	95%	5%	101	102	99	—	6.8	8.2	8.5	3.0	0.5	3.2	5.88	0.69	1.4	0.016	—	—	—	—	—

クリープ試験条件: 1040℃-14kgf/mm²

試験片は断面寸法 (クリープ試験片、5mm×5mm)

本発明: 焼成は真空 (クリープ試験片、5mm×5mm)

従来品: 焼成

焼成条件: 真空

[0087] this invention bucket is 1040 degrees C-14 kgf/mm2 while the yield rises about 5 times with 15 to 70% compared with the conventional pillar-shaped ***** , since a ***** crack does not occur. The creep fracture time of conditions improved 193 to 456h, and less than 2 double in the wings part. Moreover, although the shank part of this invention

bucket was pillar-shaped **, it was performing solution treatment and the creep fracture time of pillar-shaped **** was also more than 2 double compared with pillar-shaped **** conventionally.

[0088] If this invention bucket is compared with a single crystal bucket, this invention bucket is inferior to the single crystal bucket in high temperature creep strength.

However, by making it into pillar-shaped ** except ****, this invention bucket was able to shorten casting time, and was able to make mold cooking temperature low. As a result, since a reaction with a mold and modification of a core decreased, the rate of the defect decreased and the manufacture yield improved, this invention is a very practical high intensity bucket. Furthermore, the tensile strength near 700 degree C of pillar-shaped **** of this invention bucket was high about ten percent compared with the single crystal bucket. Although it is thought that subGUREIN of pillar-shaped ** has contributed this to improvement in tensile strength Since the tensile strength in not the creep strength in high temperature but the temperature near 700 degree C is required of a shank part, it can be said that this invention bucket which uses a wings part as a single crystal and makes it pillar-shaped ** except **** is an outstanding bucket which has the two characteristics required of a bucket.

[0089] [Example 4] nickel basis super alloy of the composition (weight %) shown in Table 5 by the method described in the example 1 was cast, and the wings part manufactured pillar-shaped **** which made it pillar-shaped ** except a single crystal and **** nearly completely. The mold in this example makes the straight mold made to bypass from a single crystal enlarged member to the projection part of an air cooling fin part in drawing 2 form, and it was made for an air cooling fin part to become pillar-shaped **. The **** crack was not looked at by the bucket after casting. Moreover, 2-60h solution treatment was performed at 1270-1285 degrees C, and 4-20h and 800-950 degrees C performed 8-100h prescription heat treatment into the alloy at 1000-1150 degrees C among the vacuum. And when 1000-1150 degrees C compared the durable temperature in creep with 4-20h and the sample which gave only 8-100h prescription heat treatment at 800-950 degrees C for 14.0 kgf/mm stress 2 or 100,000 hours, durable temperature was rising by about 15 degrees C. In this example, the crystal direction difference of pillar-shaped **** was about 5 times.

[0090]

[Table 5]

表 5

C	0.1 ~ 0.15	Cr	8.0 ~ 9.0
Co	9.5 ~ 10.5	W	10.0 ~ 11.0
Re	1.0 ~ 1.5	Mo	0.3 ~ 0.7
Ta	3.0 ~ 4.0	Al	5.5 ~ 6.0
Ti	0.5 ~ 1.5	Hf	0.7 ~ 1.0
B	0.005 ~ 0.01	Zr	0.005 ~ 0.0
Ni	残 部	—	

[0091] [Example 5] The composition shown in Table 6 by the method described in the example 1 was cast, and the wings part cast the single crystal and the bucket for gas turbines which made it pillar-shaped ** except **** nearly completely. The mold in this example adds the straight mold made to bypass from a single crystal enlarged member to the fin which is a projection part in drawing 2 as a solidification promotion passage, and it was made to become pillar-shaped ** in which a fin has good crystallinity. As a result, the **** crack was not looked at by this bucket after casting, but the fin was healthy pillar-shaped ** of less than five direction differences.

[0092] The sample which gave 1250-1285 degrees C-2-60h solution heat treatment and prescription heat treatment of 1080 degrees C - 4 h and 871 degrees C - 20 h to this bucket, and the sample of only 1080 degrees C - 4 h and 871 degrees C - 20 h prescription heat treatment were prepared after casting. As a result, the durable temperature of the sample which performed solution heat treatment in 14 kgf/mm² stress and 100,000-hour creep was improving by about 15 degrees C with all the alloys in Table 4 from the sample of only prescription heat treatment.

[0093]

[Table 6]

表 6

	C	Cr	Co	W	Re	Mo	Ta	Al	Ti	Hf	B	Zr	Ni
合金(A)	0.03 ~0.10	6.2 ~6.8	9.1 ~9.9	6.0 ~6.6	2.7 ~3.2	0.3 ~0.7	6.1 ~6.9	5.3 ~5.8	0.6 ~1.2	0.5 ~1.1	0.02 ~0.020	~0.020	残
合金(B)	0.03 ~0.10	7.3 ~8.2	4.1 ~4.9	7.4 ~8.4	~0.3	0.1 ~0.7	5.6 ~6.4	5.3 ~5.8	0.6 ~1.2	0.5 ~1.1	0.02 ~0.020	~0.020	残
合金(C)	0.03 ~0.10	7.3 ~8.6	8.8 ~9.5	9.1 ~9.7	~0.3	0.2 ~0.6	2.9 ~3.5	5.2 ~5.7	0.4 ~1.1	0.5 ~1.35	0.002 ~0.020	~0.020	残

[0094] [Example 6] The bucket for gas turbines was cast according to the method shown in the example 1 using this invention alloy shown in Table 7. However, even if it passed the platform 15 here, mold drawer speed was not changed, but the whole was cast at the mold drawer speed of 10 cm/h. The same heat treatment as an example 1 was given after

casting, several miniature samples which have two crystal grains from this bucket were started, and the difference of the crystal direction of the right-angled direction and the relation of creep strength were investigated in the solidification direction of two crystal grains. In addition, the sample was extracted to **** in parallel. Moreover, JP,3-75619,B which is an alloy only for a single crystal The alloy shown in the number was evaluated as a comparison alloy. It casts in the casting conditions same also about a comparison alloy as this invention alloy, and is JP,3-75619,B. The examination was presented after giving heat treatment shown in the number. A result is shown in Table 8. 1040 degrees C of this result to this invention alloy, 14 kgf/mm² Creep strength will hardly be influenced by the crystal direction difference, if the difference of a crystal direction is less than 15 degrees. On the other hand, it turns out that the comparison alloy which is exclusively for a single crystal cannot permit the difference of few crystal directions, either.

[0095]

[Table 7]

表 7

(wt%)

C	Cr	Co	W	Re	Mo	Ta	Al	Ti	Hf	B	Zr	Ni
0.05	5.5	9.0	8.0	2.8	0.3	3.0	5.5	0.5	0.7	0.015	0.0025	残
~0.09	~7.0	~9.5	~9.0	~3.1	~0.7	~4.0	~6.0	~0.9	~0.8	~0.020	~0.005	残
0.07	6.6	9.2	8.5	3.0	0.5	3.2	5.68	0.69	1.4	0.016	0.006	残

[0096]
[Table 8]

表 8

	試験片採取位置	結晶方位差	クリープ破断時間
本発明合金 No. 1	翼部	1度以下	4 5 6 h
	翼部	3度	4 4 7 h
	シャंक部	5度	4 3 8 h
	シャंक部	7度	4 4 1 h
本発明合金 No. 2	翼部	1度以下	4 4 6 h
	翼部	7度	4 3 7 h
	シャंक部	12度	4 2 2 h
	シャंक部	15度	4 1 8 h
比較合金 No. 1	翼部	1度以下	4 3 6 h
	翼部	3度	4 3 3 h
	シャंक部	5度	4 2 7 h
	シャंक部	7度	4 1 1 h
比較合金 No. 2	翼部	1度以下	4 4 6 h
	翼部	7度	2 0 5 h
	シャंक部	8度	1 9 8 h
	シャंक部	12度	0.5 h

[0097] [Example 7] Drawing 7 is the sectional view of the rotation portion of the gas turbine which has the gas turbine bucket of this invention of an example 2.

[0098] 30 a turbine stub shaft and 33 a turbine rotor blade and 43 A turbine stacking bolt, 38 -- a turbine spacer and 49 -- DISUTANTO piece and 40 -- as for compressor stacking BORUDO and 39, a compressor disk and 37 are [a turbine disc and 41] holes a compressor stub shaft and 34 a compressor blade and 38 a nozzle and 36. The compressor disks 36 are [those with 17 step and the turbine rotor blade 33 of the gas turbine of this invention] three steps of things. The turbine rotor blade 33 also has four steps of cases, and can apply the alloy of this invention to all.

[0099] The form with a main gas turbine in this example consists of heavy TEYUTI type, 1 axis type, a level division casing, and a stacking type rotor. ***** according [according to / in a compressor / 17 step axial flow type / a turbine] to three-step impulse type and 1 or 2-step air cooling and a burner have the Bath flow type, 16 tins, and a slot cool method.

[0100] The DISUTANTO piece 39, a turbine disc 34, a spacer 38, and the stacking bolt 33 [weight] C0.06-0.15%, less than Si1%, and Mn1.5% The total-destruction-by-fire return martensite steel which consists [9.5 to 12.5% of Cr, 1.5 to 2.5% of nickel, and 1.5 to 3.0% of Mo] of the remainder Fe N 0.04 to 0.15% V 0.1 to 0.3% in 0.03 to 0.15% of Nb is used hereafter. As the characteristic in this example **** strength is [90-120kg/mm2 and] 0.2%. 70-90kg/mm2 of power-proof, 10 to 25% of a pace of expansion, 50 to 70% of a contraction percentage, V notch shock value 5 - 9.5 kg-m/cm2, 450 degree C 105h Creep breaking strength of 45-55kg/mm2 It was.

[0101] It has three steps of turbine rotor blades 33, and they made temperature of combustion gas according 14.7, the temperature of 400 degrees C, and first rank bucket inlet temperature to 1,300 degrees C and a burner in the compression pressure of a compressor 1450-degree-C class using what was manufactured in the example 1 to the

first rank. moreover, 280mm (160mm of wings parts, and a platform part or subsequent ones 120mm in length) of length of a wing which becomes the 2nd step of the turbine rotor blade 33 from the many crystallines of equivalent alloy composition -- and Similarly the solid wings of 350mm (230mm of wings parts, 120mm of others) of length of a wing of many crystallines were manufactured using the equivalent alloy composition same in the 3rd step. The process was based on the precision casting process by the conventional lost wax process.

[0102] Known Co basis alloy is used for a turbine nozzle 40, and the thing which had what consists from the first rank to three steps of one wings part by vacuum precision casting formed is used. The length of a wings part has the length equivalent to the length of a bucket, and has pin fin cooling, impingement cooling, and film cooling structure. Although an one-step nozzle is restrained at sidewall both ends, the 2nd step and the 3rd step are restrained at one side by the side of the sidewall perimeter. An intercooler is prepared in a gas turbine.

[0103] As for the power generation output obtained by this example, 50 MW is obtained, and, as for the thermal efficiency, 33% or more of high thing is obtained.

[0104] [Example 8] Drawing 8 is the schematic view showing the 1 axis type combined-cycle-power-generation system used together with the steam turbine using the gas turbine of an example 7.

[0105] A steam turbine is driven with the steam which collected and obtained the exhaust gas energy of the gas turbine while driving the gas turbine by using liquefied natural gas (LNG) as fuel in recent years, when generating electricity using a gas turbine. It is in the tendency which adopts what is called a combined cycle power generation method to have made it drive a dynamo by this steam turbine and gas turbine. In this combined cycle power generation method, the high-fee efficiency of about 45% or more becomes possible compared with 40% of the thermal efficiency in the case of the conventional steam turbine independent by the following system composition. In such a combined cycle power generation plant, further, two ways with liquefied petroleum gas (LPG) are planned from liquefied natural gas (LNG) ****, or, these days, it tries to aim at carrying out smoothly of plant employment, and improvement in economical efficiency by realization of the multifuel firing of LNG and LPG.

[0106] Air goes into the air compressor of a gas turbine through an air intake filter and an air intake siren first, and an air compressor compresses air and sends compressed air to a low NOx burner. And in this compressed air, fuel is injected, it burns, and high temperature gas of 1400 degrees C or more is made from a burner, this high temperature gas works in a turbine, and power generates it.

[0107] The exhaust air of 530 degrees C or more discharged from the turbine is sent to an exhaust heat recovery boiler through an exhaust air silencer, collects the thermal energies. under gas turbine exhaust air, and generates high-pressure steam of 530 degrees C or more. The NOx removal equipment by dry type ammonia contact reduction is formed in this boiler. Exhaust gas is discharged outside from the chimney which is also hundreds of 3-piece set type m. The generated high-pressure and low-pressure steam is sent to the steam turbine which really [height pressure] consists of a rotor.

[0108] Moreover, the steam which came out of the steam turbine flows into a condenser, vacuum deaeration is carried out and it becomes condensation, and ** pressure of the condensation is carried out with a condensate pump, it turns into supplying water, and is

sent to a boiler. And a gas turbine and a steam turbine drive a dynamo from both the axis end, respectively, and power generation is performed. The steam used with a steam turbine other than air as a cooling medium may be used for cooling of the gas turbine wings used for such combined cycle power generation. although air is generally used as a cooling medium of wings, as compared with air, specific heat boils steam markedly, and since [large and] weight is light, a chilling effect is large.

[0109] Since it becomes a gas turbine can obtain 50,000kW by this combined power generation system, can obtain 80,000kW power generation in 30,000kW total with a steam turbine, and compact [the steam turbine in this example] Compared with a large-sized steam turbine, manufacture becomes possible economically to the same power generation capacity, and big Merritt which can be economically operated to change of a production of electricity is obtained.

[0110] It can be made the steam turbine concerning this invention with a height pressure integral-type steam turbine, and the increase in the single opportunity output of a turbine can be aimed at by raising steam pressure power 100atg of the main steam entrance part of this height pressure integral-type steam turbine, and the temperature of 538 degrees C. The increase in a single opportunity output needs to increase the length of a wing of the last stage bucket to 30 inches or more, and needs to increase steamy flux. The braid implanted in the height pressure integral-type rotor shaft is equipped with 13 or more steps of steam turbines concerning this invention, steam passes along a steamy control valve, and they are 538 degrees C and 88atg like the above-mentioned from a steam inlet. It flows by high temperature high pressure. Steam flows into one way from an entrance, serves as steamy temperature of 33 degrees C, and 722mmHg, and is discharged by the exit from the braid of the last stage. The forged steel of low alloy steel [shaft / concerning this invention / height pressure 1 mold rotor / nickel-Cr-Mo-V] is used. The thicket part of the braid of a rotor shaft has become disk-like, and is cut and manufactured by one from a rotor shaft. The length of a disk part becomes so long that the length of a braid is short, and lessens vibration.

[0111] As for the height pressure integral-type rotor shaft concerning this example, less than Si0.1%, less than Mo0.3%, 1.0 to 2.0% of nickel, 1.0 to 1.7% of Cr, and 1.0 to 2.0% of Mo consist of the remainder Fe V 0.20 to 0.3% C0.18-0.30%. Annealing is given by water spray cooling at 650-680 degrees C after hardening at 900-1050 degrees C.

[0112] Although the composition of a plant arranges 1 set of power generation systems which consist of a gas turbine, exhaust heat recovery boilers, steam turbines, and one dynamo each to 1 axis type combined 6 sets, others, Steam can be obtained by exhaust gas after one dynamo's combining to one gas turbine and combining 6 sets of these, and it can be considered as the multiple spindle type used as one a steam turbine and one dynamo.

[0113] Deactivation is realized in the combination of the easy gas turbine in a short time, and a small and simple steam turbine, and, for this reason, the output adjustment of combined cycle power generation is the optimal as middle load fire power which was made easily and conformed to change of demand.

[0114] Since the reliability of a gas turbine is increasing by leaps and bounds by development of the latest technology and the combined cycle power generation plant constitutes the system from combination of a small capacity machine, even if failure should occur, the influence can be limited to a part, and it is a reliable power supply.

[0115]

[Effect of the Invention] Since the bucket for gas turbines which has high creep strength is obtained according to this invention, there is a prominent effect of aiming at improvement in thermal efficiency of the combined cycle power generation plant system using the gas turbine and it by the reinforcement of a bucket and the rise of temperature of combustion gas.

[0116] Moreover, according to the manufacturing process of the bucket for gas turbines by this invention, the rate of the yield in bucket manufacture can be improved.

[Brief Description of the Drawings]

[Drawing 1] It is the perspective view of the bucket for gas turbines concerning this invention.

[Drawing 2] It is the composition figure showing the outline of the manufacturing process of the bucket for gas turbines concerning this invention.

[Drawing 3] It is the figure showing the physical relationship of the top view of the core shown in this example, and a bucket.

[Drawing 4] It is the comparison figure showing the high temperature intensity of pillar-shaped ***** obtained by this invention, and the conventional pillar-shaped *****.

[Drawing 5] It is the sketch figure showing the situation of the **** crack looked at by pillar-shaped ***** manufactured by the one-way solidifying method.

[Drawing 6] It is the characteristic figure showing the relation of the amount of C and quantity (B+Zr) which can dissolve deposit gamma' ** in gamma-phase, and the relation of a **** crack, without producing initial melting of an alloy.

[Drawing 7] It is the whole gas turbine composition figure concerning this example.

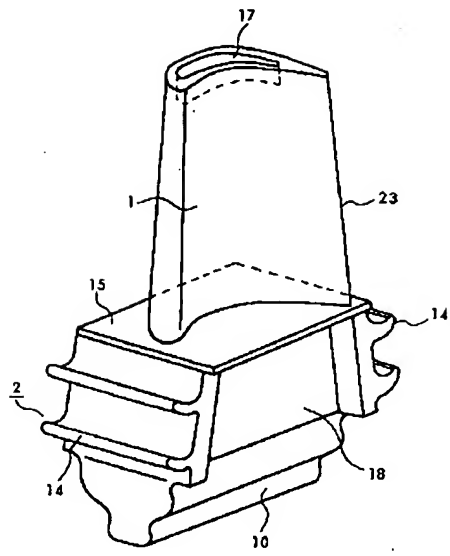
[Drawing 8] It is the whole combined cycle power generation plant system chart concerning this example.

[Explanations of letters or numerals]

1 [-- A mold heating furnace, 5 / -- ****, 6 / -- Casting,] -- A wings part, 2 -- A root part, 3 -- A fusion furnace, 4 7 [-- A starter, 11 / -- Water-cooled copper CHIRUPU rate,] -- A core, 8 -- A ceramic mold, 9 -- A selector, 10 12 [-- A platform, 16 / -- A dove tail, 18 / -- A shank, 33 / -- A bucket, 34 / -- A turbine disc, 36 / -- A compressor disk, 38 / -- A spacer, 40 / -- ****.] -- A vacuum pump, 13 -- A furnace shell, 14 -- An air cooling fin, 15

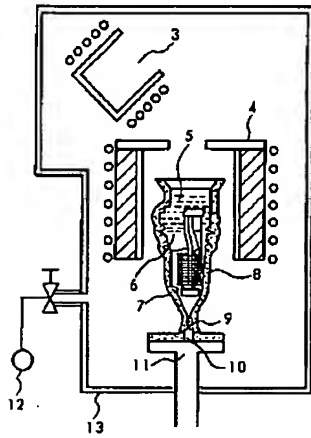
[Drawing 1]

図 1



[Drawing 2]

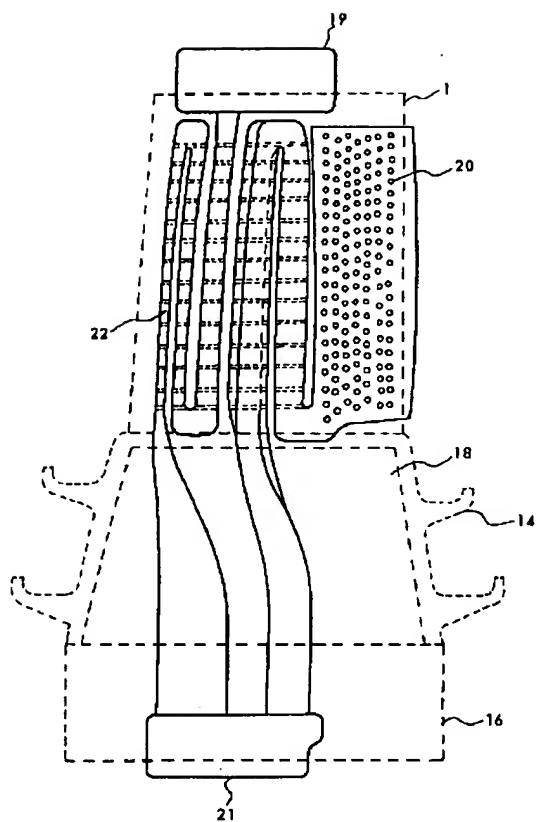
図 2



3…溶解炉 4…誘導加熱炉 5…溶湯
6…誘物 7…中子 8…誘型
9…セレクタ 10…スタータ 11…水
冷チルプレート 12…真空ポンプ
13…炉殻

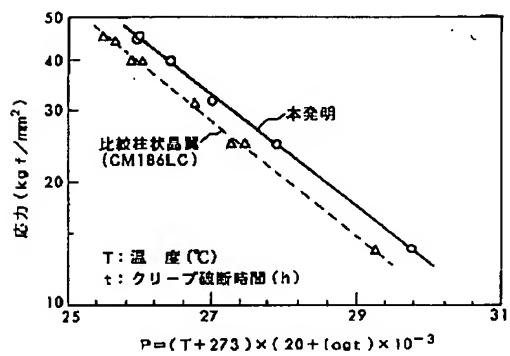
[Drawing 3]

図 3



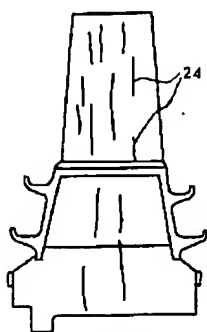
[Drawing 4]

図 4



[Drawing 5]

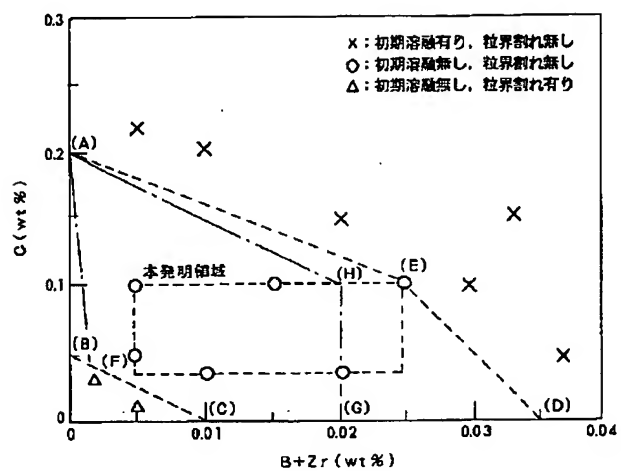
図 5



24…粒界割れ

[Drawing 6]

図 6



[Drawing 7]

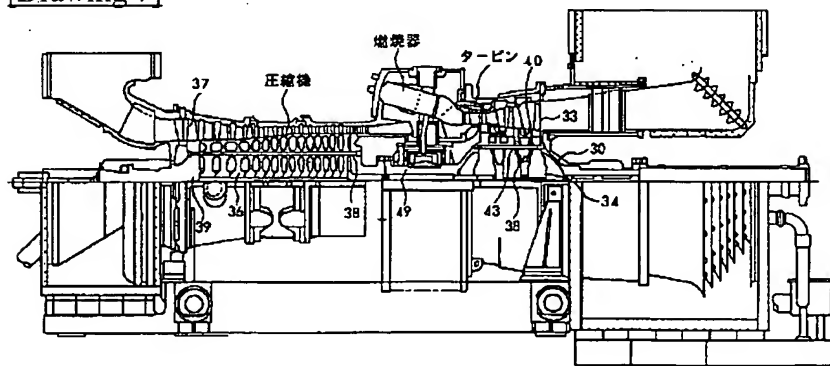
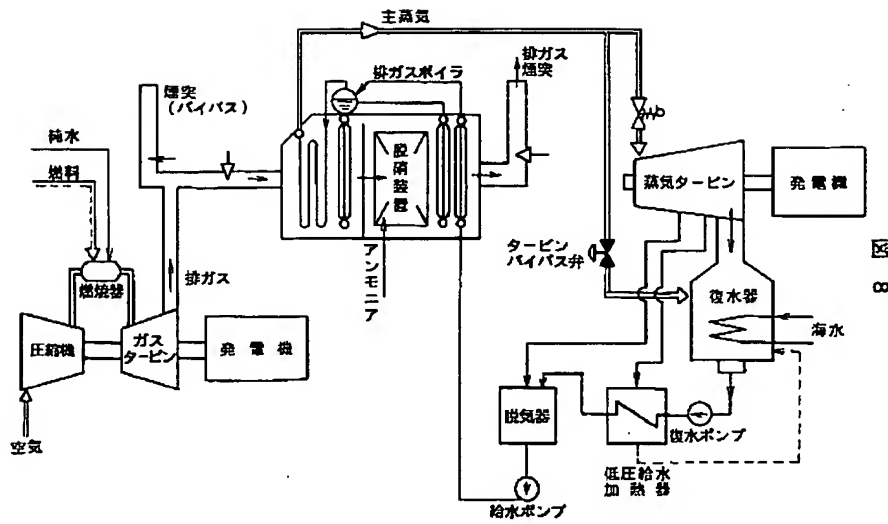


図 7

[Drawing 8]



[Translation done.]